Received: 12 November 2020 | Revised: 12 May 2021 | Accepted: 7 June 2021

DOI: 10.1111/clr.13807

ORIGINAL ARTICLE

CLINICAL ORAL IMPLANTS RESEARCH WILEY

Treatment concepts of horizontally deficient ridges—A retrospective study comparing narrow-diameter implants in pristine bone with standard-diameter implants in augmented bone

Eik Schiegnitz[1] | Peer W. Kämmerer[1] | Philipp Hellwich[1] | Jochem König[2] | Keyvan Sagheb[1] | Bilal Al-Nawas[1]

[1]Department of Oral and Maxillofacial Surgery, Plastic Surgery, University Medical Centre of the Johannes Gutenberg-University, Mainz, Germany

[2]Institute of Medical Biometry, Epidemiology and Informatics, Johannes Gutenberg-University, Mainz, Germany

Correspondence
Eik Schiegnitz, Department of Oral and Maxillofacial Surgery, Plastic Surgery, University Medical Centre of the Johannes Gutenberg-University. Augustusplatz 2, 55131 Mainz, Germany.
Email: eik.schiegnitz@unimedizin-mainz.de

Abstract

Objectives: To compare clinical and radiological outcomes of narrow-diameter implants (NDI) placed in pristine bone to standard-diameter implants placed in combination with horizontal bone augmentation procedures (SDI+A) for horizontally deficient alveolar ridges.

Material and Methods: For this retrospective study, the outcome of 597 NDI (⌀ 3.3 mm, 272 patients), inserted in pristine bone, were compared with 180 SDI (⌀ 4.1 mm, 83 patients), inserted in combination with horizontal augmentation procedures. Oral health-related quality of life was assessed in patients available for recall.

Results: After a mean follow-up of 37.6 ± 40 months for the NDI and of 42.4 ± 49 months for the SDI+A, survival rates were 96.1% for NDI and 95.6% for SDI+A. Cumulative 5-year and 10-year implant survival rates were 94.3% and 92.2% for the NDI group and 97.0% and 88.3% for the SDI+A group, indicating no significant difference ($p = .89$). According to the criteria of Buser et al., an implant success rate of 84.3% was obtained for the NDI and an implant success rate of 81.3% for the SDI+A ($p = .79$). Regarding oral health-related quality of life, a similar and high patient satisfaction could be observed in both groups.

Conclusions: NDI without augmentation procedures showed a similar clinical outcome as SDI in combination with augmentation procedures after a follow-up of more than 3 years. Therefore, NDI might be a reasonable alternative in cases of horizontal bone atrophy (no clinical trial registration as patient inclusion started 2003).

KEYWORDS

clinical research, clinical trials, patient centered outcomes, surgical techniques

The data from this study are part of the dissertation work submitted to Johannes Gutenberg University, Mainz as part of doctoral thesis of Philipp Hellwich.

1 | INTRODUCTION

Narrow-diameter implants are in general defined as implants with a diameter ≤3.5 mm (Schiegnitz & Al-Nawas, 2018). However, this classification does not consider the different clinical indications of the commercially available NDI. Therefore, the classification of Schiegnitz et Al-Nawas was introduced during the Sixth ITI Consensus Conference (Jung et al., 2018; Schiegnitz & Al-Nawas, 2018). In this classification, NDI are divided into the following three categories:

Category 1: Implants with a diameter of <2.5 mm ("Mini-implants").

Category 2: Implants with a diameter of 2.5 mm to <3.3 mm.

Category 3: Implants with a diameter of 3.3 mm to 3.5 mm.

There are several clinical studies that show an increase in terms of quality of life after treatment with NDI of category 1 (Elsyad, 2016; Enkling et al., 2017; Preoteasa et al., 2014). Several studies also report acceptable success rates even for immediately loaded mini implants (Park et al., 2019). Comparing the survival rates between NDI and standard-diameter implants (SDI), a recent meta-analysis showed that the mean survival rates of NDI of category 1 (⌀ <2.5 mm) were significantly lower than the survival rates of SDI (Schiegnitz & Al-Nawas, 2018). These results are not surprising, as these mini-implants were generally inserted in highly atrophic edentulous jaws that represent surgically challenging situations. For NDI of category 2, a recent clinical study investigated the 2-year implant survival and success rates of single, narrow, immediately loaded implants (3.1 mm diameter). The results indicated both implant success and survival rates of 100% due to stable marginal bone levels and shallow probing pocket depths after 2 years of follow-up. In a 5-year prospective multicenter study, the clinical and radiological performance of immediately provisionalized 3.0-mm-diameter tapered implants was analyzed. The 1-year interim results showed a survival rate of 96.7% and marginal bone level changes from insertion to 12 months of- 0.25 ± 1.38 mm. Papilla index score and PES improved at the 1-year follow-up. In a recent study no significant differences in bone loss around NDI (3.3 mm diameter) 2 years after implant loading were illustrated compared with conventional-diameter implants (4.1 mm) (Corcuera-Flores et al., 2020). Finite element analysis showed that with an increase of implant diameter, stress

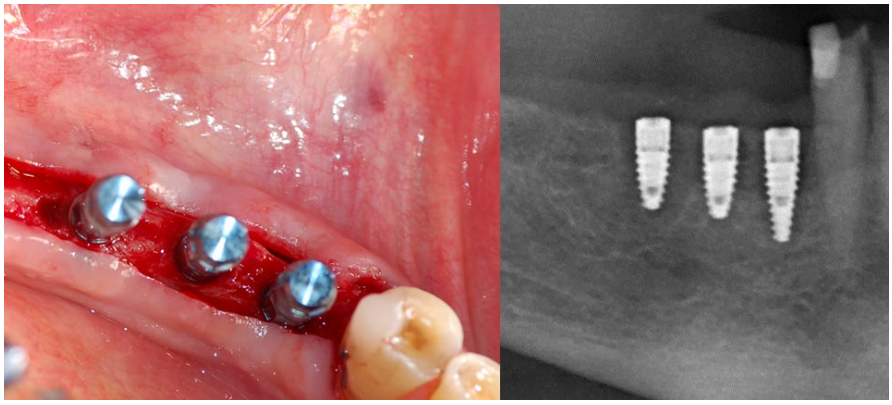

FIGURE 1 Clinical case of three 3.3 mm NDI, inserted in pristine bone

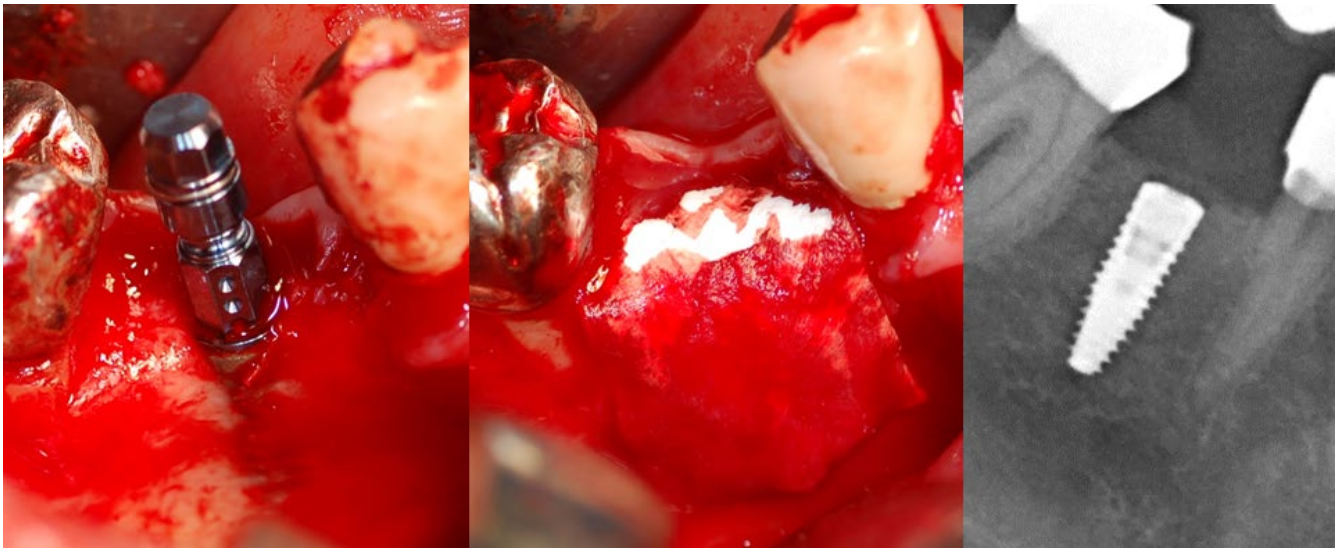

FIGURE 2 Clinical case of a 4.1 mm SDI in combination with horizontal augmentation

and strain on the implant-bone interfaces significantly decreased, especially when the diameter increased from 3.3 to 4.1 mm (Ding et al., 2009).

However, another finite element analysis indicated that Ti and Ti-Zr alloys can be used successfully as narrow-diameter implants in the second premolar area (Cinel et al., 2018). Meta-analysis indicated comparable implant survival rates between NDI of category 2 (⌀ 2.5 mm to <3.3 mm) and category 3 (⌀ 3.3 mm to 3.5 mm) compared to SDI (Schiegnitz & Al-Nawas, 2018).

All of these in meta-analysis included studies that compared survival rates of NDI and SDI, both inserted in pristine bone. This comparison is, from a clinical point of view, insufficient. The correct comparison would contain NDI inserted in pristine bone and SDI inserted in horizontally augmented bone in the indication of horizontally deficient alveolar ridges. However, to our best knowledge, studies on this topic are missing so far. Therefore, the aim of this study was to examine for the first time the clinical longtime survival and success rates of NDI and SDI in combination with augmentation procedures. Consequently, the question should be assessed if NDI support the hypothesis of the necessity of a critical buccal bone thickness as displayed by several authors (Spray et al., 2000) in the form of minimization of dehiscences and the prevention of long-term complications.

2 | MATERIALS AND METHOD

2.1 | Study design

In this clinical study, the clinical and radiological outcome of NDI (⌀ 3.3 mm, Straumann), inserted in pristine bone and SDI (⌀ 4.1 mm, Straumann), inserted in horizontally augmented bone, were evaluated retrospectively (Figures 1,2). Ethical approval was obtained from the ethical committee of Rhineland-Palatinate, Germany (Registration number: 2019–14414, Landesärztekammer Rheinland-Pfalz). The study was conducted in accordance with the Helsinki declaration of 1975 as revised in 2000 and the study is in compliance with the STROBE guidelines. All implants were inserted by experienced surgeons in the Department of Oral and Maxillofacial Surgery of the University Medical Centre Mainz, Germany, between January 2003 and December 2018. Patients presenting with a deficient horizontal ridge (<4.5 mm) were informed in detail about both treatment concepts (NDI without augmentation versus SDI with lateral augmentation) and their advantages and disadvantages.

2.2 | Inclusion criteria

1. Patients receiving NDI (⌀ 3.3 mm, Straumann), inserted in pristine bone or SDI (⌀ 4.1 mm, Straumann), inserted in horizontally augmented bone;
2. Patient age ≥18 years

2.3 | Exclusion criteria

1. Patients without detailed baseline medical data;
2. Patients with vertical augmentation procedures;
3. Heavy smokers (>10 cigarettes per day);
4. Uncontrolled diabetes mellitus;
5. Complete edentulism.

2.4 | Surgical procedure and outcome assessment

All surgeries were performed under local anesthesia and according to the protocol of the manufacture. For patients, that were accessible for a clinical follow-up examination, success rates according to Buser et al. (1990) were examined. These criteria were in accordance with position of the implant, mobility of the implants, peri-implant radiographic translucency, infection and/or inflammation and absence of chronic pain, dysesthesia and/or foreign body feeling. Furthermore, success rates according to Albrektsson et al. (1986) were analyzed. These criteria were in accordance with implant's survival time or time to loss, mobility of the implant, peri-implant radiographic translucency, bone loss, signs of infection/inflammation and lesions of the anatomical structures. Plaque index according to Mombelli et al. (1987) was evaluated. Peri-implant mucositis and peri-implantitis were analyzed according to Berglundh et al. (2018). Number and type of technical complications and a comparative analysis according to prosthesis design could not be evaluated, as most of the patients got their prosthetical supply alio loco. Radiography via orthopantomogram or intraoral radiographs was conducted at the time of examination. The up-to-date and the postoperative radiograph were compared to analyze the distance from the implant-abutment periphery to the apex of the implant as described before (Schiegnitz et al., 2016). For evaluation of Oral Health-Related Quality of Life (OHRQoL), the OHIP-G 14 was applied (John et al., 2002). In addition, a questionnaire with the following questions was used (score 1 to 10): (a) How do you rate your implant? (b) How do you rate the operation? (c) How do you rate the implant-supported prosthesis? Higher scores imply a stronger positive influence on OHRQoL, in contrast lower scores indicate negative OHRQoL.

2.5 | Data analysis

For the statistical analysis, implant-related data were calculated. The nature of this experiment was descriptive, exploratory without a primary hypothesis. Therefore, we report descriptive *p*-values of tests and no adjustment to multiple testing was done. The Kaplan–Meier survival function was applied for the description of survival rates. To examine the statistical difference between treatment groups with respect to implant survival, a log-rank test was calculated. We fitted a cox model adjusted for age and gender, allowing for clustering due to multiple implants per patient and we report 95% Wald robust confidence limits. For comparisons with respect to success rates,

we applied a chi-squared test, and for comparisons with respect to OHrQoL, we applied Student's *t*-test. The analyses were conducted using SPSS version 20.0 (IBM).

3 | RESULTS

3.1 | Study data and survival rates

In the investigated period 597 NDI in 272 patients and 180 SDI in 83 patients in combination with horizontal augmentation procedures were inserted. In the NDI group 153 patients were female and 119 patients were male. The mean age was 64 years (range 18–97). 328 NDI were inserted in the maxilla (159 anterior maxilla, 169 posterior maxilla) and 269 in the mandible (100 anterior mandible, 169 posterior mandible). Length of the included NDI ranged from 8 to 14 mm. Regarding implant design, 145 NDI were Tissue Level implants and 452 NDI were Bone Level implants. In the SDI+A group 50 patients were female and 33 male. The mean age was 60 years (Range 22–90). 102 SDI+A were inserted in the maxilla (49 anterior maxilla, 53 posterior maxilla) and 78 in the mandible (12 anterior mandible, 66 posterior mandible). Length of the included SDI+A ranged from 6 to 16 mm. 49 SDI+A were Tissue Level implants and 131 SDI+A were Bone Level implants. For the NDI group mean follow-up was 37.6 ± 40 months (range 1–186 months) and during the follow-up 23 NDI failed. Mean follow-up of the SDI+A group was 42.4 ± 49 months (range 1–194 months) and 8 SDI+A failed. Cumulative 5-year and 10-year implant survival rates were 94.3% and 92.2% for the NDI group and 97.0% and 88.3% for the SDI+A group, indicating no significant difference ($p = .86$, hazard ratio adjusted for age and gender: $p = .87$, CI: 0.48 to 2.41, Figure 3). Cox regression showed the following hazard ratio adjusted for age and gender: HR 0.93, 95% CI: 0.32 to 2.69, favoring NDI. Tissue Level implants in the NDI group showed higher survival rates than Bone Level implants in the NDI group, however not statistically significantly different (97.2% versus. 95.8%; log rank test $p = .12$; Figure 4). Tissue Level implants in the SDI+A group showed comparable survival rates to Bone Level implants in the SDI+A group (95.9% versus. 95.4%; $p = .74$; Figure 5).

3.2 | Clinical follow-up and success rates

For evaluation of success rates, 53 patients with 102 NDI and 32 patients with 80 SDI remaining in situ attended a clinical follow-up examination. The Plaque Index according to Mombelli et al. (1987) showed that 83.3% of NDI implants and 90% of the SDI+A implants had a satisfactory degree of oral hygiene (grade 0 and 1). According to Berglundh et al. 17.6% of the NDI implants showed peri-implant mucositis and 5.9% peri-implantitis. In the SDI+A group, 16.3% of the implants showed peri-implant mucositis and 6.3% peri-implantitis. The average probing depth of the SDI group was vestibular 2.16 ± 0.55 mm, oral 2.14 ± 0.42 mm, mesial 2.34 ± 0.78 mm, and distal 2.35 ± 0.70 mm. For the SDI-A group average probing depth was vestibular 2.04 ± 0.54 mm, oral 2.03 ± 0.50 mm, mesial 2.15 ± 0.68 mm, and distal 2.11 ± 0.57 mm. The mean bone loss for the NDI group was −0.33 ± 0.8 mm (mesial mean bone loss: −0.31 ± 0.8 mm, distal mean bone loss: −0.35 ± 0.9 mm). In the SDI+A group a mean bone of −0.47 ± 1.2 mm was measured (mesial mean bone loss: −0.49 ± 1.20 mm, distal mean bone loss: −0.46 ± 1.20 mm). These results may indicate a lower marginal bone

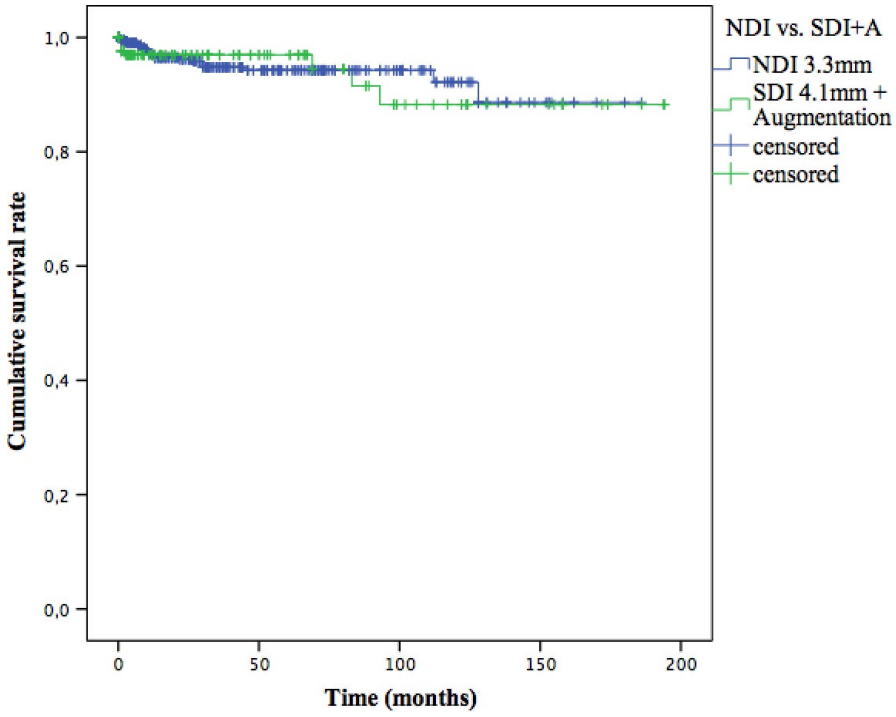

FIGURE 3 Cumulative survival rate according to Kaplan–Meier for NDI and SDI+A ($p = .86$, hazard ratio adjusted for age and gender: $p = .87$, CI: 0.48–2.41)

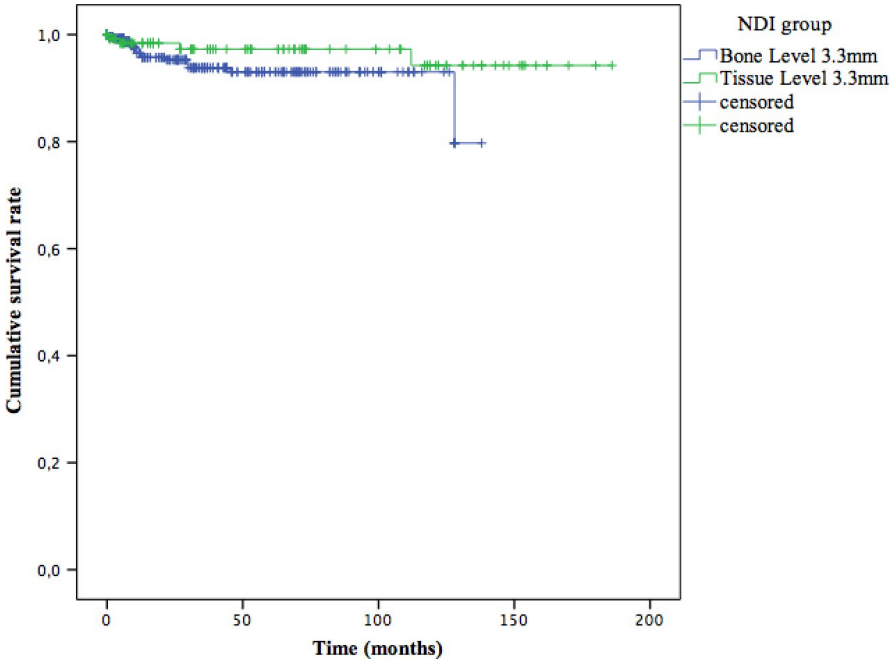

FIGURE 4 Cumulative survival rate according to Kaplan–Meier for Tissue Level and Bone Level implants of group NDI (97.2% versus. 95.8%; log rank test $p = .12$)

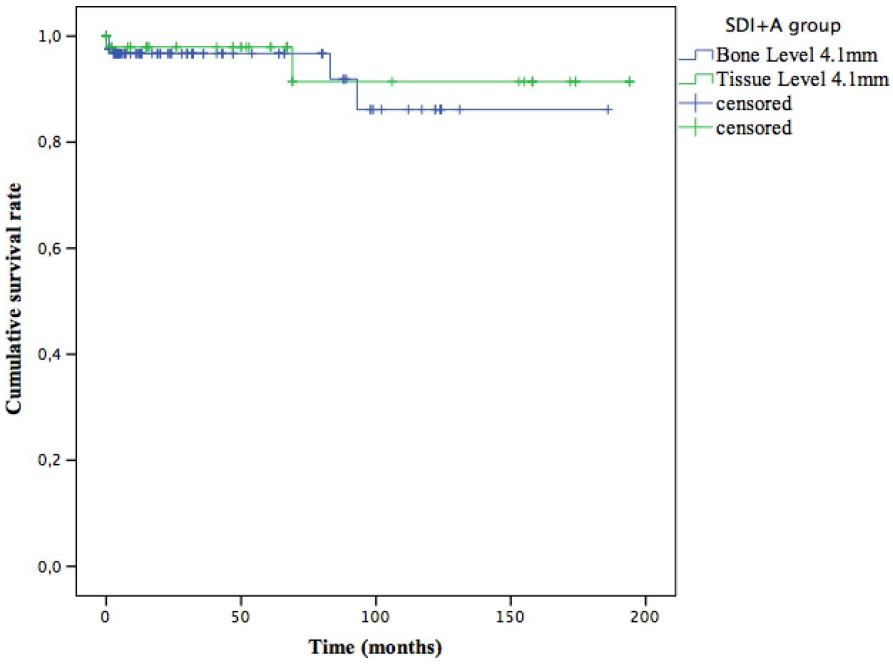

FIGURE 5 Cumulative survival rate according to Kaplan–Meier for Tissue Level and Bone Level implants of group SDI+A (95.9% versus. 95.4%; $p = .74$)

loss in patients receiving NDI in pristine bone compared to patients receiving SDI in augmented bone, however not statistically significant ($p = .33$). After a mean clinical follow-up of 60 ± 59 months the following success rates were seen: Application of the criteria of Albrektsson et al. (1986) indicated a n85.3% implant success rate for the NDI group and an 82.5% implant success rate for the SDI+A group ($p = .48$; hazard ratio adjusted for age and gender: HR 0.7, 95% CI: 0.27 to 1.81 favoring NDI. By the definition of Buser et al. (1990), an implant success rate of 84.3% was obtained for the NDI and an implant success rate of 81.2% for the SDI+A ($p = .79$; hazard ratio adjusted for age and gender: HR 0.78, 95% CI: 0.32 to 1.90 favoring NDI).

3.3 | Oral health-related quality of life

57 patients of the NDI group and 32 patients of the SDI+A group completed the OHIP-G-14 and the questionnaire. Mean OHIP-G 14 scores were 4.2 ± 8 (range 0–53) for the NDI group and 3.8 ± 5 (range 0–19) for the SDI+A group ($p = .841$). The answered OHRQoL questionnaire showed the following results: regarding all three questions, "How do you rate your implant?" (NDI: 8.8 ± 1.6; SDI+A: 9.2 ± 1.1; $p = .25$), "How do you rate the operation?" (NDI: 9.3 ± 1.1; SDI+A: 9.4 ± 1.2; $p = .62$) and "How do you rate the implant-supported prosthesis?" (NDI: 8.8 ± 1.8; SDI+A: 9.1 ± 1.5; $p = .56$) no significant differences were seen.

4 | DISCUSSION

Implant-based treatment concepts of horizontally deficient alveolar ridges include different kinds of augmentation procedures like alveolar ridge splitting/expansion, onlay bone grafts, and Guided Bone Regeneration (GBR). These augmentations procedures are well described in the literature with high success rates (Al-Nawas & Schiegnitz, 2014; Sagheb et al., 2017; Starch-Jensen & Becktor, 2019). These GBR procedures could compensate for dimensional changes and could optimize the aesthetic and functional outcome. However, these augmentation procedures are associated with complications such as postoperative pain, infections, nerve damage, bone fractures, hemorrhage, wound dehiscences, and implant or augmentation failures (Al-Nawas & Schiegnitz, 2014; Klein et al., 2014; Moy & Aghaloo, 2019). In addition, they are time and cost-consuming. In medically compromised patients (e.g., patients with anticoagulant treatment, a history of radiation in the head and neck region or with antiresorptive medication) augmentation procedures may carry a higher risk of complications (Chappuis et al., 2018; Schiegnitz et al., 2014; Walter et al., 2016). Therefore, alternative concepts such as NDI are coming more and more in the clinical and scientific focus. Regarding this surgical perspective, NDI may have a lower risk of post-operative complications and are less technically demanding in terms of surgery. In addition, considering the phrase "less implant, more bone" NDI may present more buccal bone than SDI. There is recent evidence that a thin buccal bone wall at implant insertion will undergo significant resorption during healing, leading to vertical bone loss and inducing a peri-implant bone defect in the crestal area prior to functional loading (Monje et al., 2019). In a recent prospective, controlled, clinical study the potential influence of implant diameter and anatomic factors on the need for bone augmentation procedures when replacing congenitally missing lateral incisors was examined (Roccuzzo et al., 2021). In this study patients with congenitally missing lateral incisors with a mesio-distal distance between the canine and the central incisor of 5.9–6.3 mm received a 2.9 mm diameter implant while 3.3 mm diameter implants were inserted when the distance was 6.4–7.1 mm. The results showed that the thickness of the facial bone after implant osteotomy was statistically significantly larger in the 2.9 diameter group compared to the 3.3 diameter group supporting the hypothesis that NDI present more buccal bone. However, from a prosthetic perspective, NDI inserted in wide tooth gaps need to be placed vertically deeper to allow a harmonious emergence profile which may be accompanied by a risk of enhanced peri-implant pocket depth and therefore a higher risk for peri-implantitis (Monje et al., 2019). In addition, Katafuchi et al. showed that an emergence angle of >30 degrees is a significant risk indicator for peri-implantitis (Katafuchi et al., 2018). Future research will have to clarify if the increased need for augmentation procedures using SDI outweighs the risk of using NDI in wider tooth gaps.

Our results showed that NDI, inserted in pristine, horizontally deficient alveolar ridges and SDI, inserted in horizontally augmented alveolar ridges have comparable survival rates, success rates, and marginal bone loss. As this is a retrospective study, causal statements on the results usually should not be made. Therefore, the results should be interpreted with caution. In the international literature, to our best knowledge, we found only studies that compare NDI with SDI, both inserted in pristine bone. In a randomized, controlled, multicenter clinical study, 50 patients in need of a single tooth replacement in the anterior or premolar region of the mandible or maxilla were included, if the site could accommodate a 4.1-mm-diameter implant (Ghazal et al., 2019). The patients received a 3.3 mm (test group) or a 4.1 mm bone-level implant (control group). Implants were temporarily restored at 3 to 4 weeks after insertion and definitive restorations were delivered 4 to 6 months after placement. The success and survival rates at 12 months post-loading were 100% for both groups. Mean crestal bone loss was significantly lower in the NDI group (−0.27 ± 0.34 mm) compared to the SDI group (0.48 ± 0.67 mm; $p = .02$). No significant difference was seen in gingival recession and patient satisfaction. The author concluded that NDI could be a valid treatment for narrow spaces and have the potential to avoid the need for bone augmentation. Trbakovic et al. examined clinical and radiological follow-up of 4 different NDI (⌀ 3.0 mm, ⌀ 3.25 mm, ⌀ 3.3 mm) of category 3, replacing maxillary laterals and mandibular incisors (Trbakovic et al., 2018). After a mean follow-up of 63.3 months implant survival was 97.2%. In a further clinical study 2-year implant survival and success rates of single, narrow, immediately loaded implants (⌀ 3.1 mm) placed in fresh extraction sockets or healed sites in the anterior region were reported (Peron & Romanos, 2020). Implant success and survival rates were both 100% due to stable marginal bone levels and shallow probing pocket depths. A 5-year prospective multicenter study analyzed the clinical and radiological outcome of immediately provisionalized 3.0 mm diameter tapered implants in patients needing implant rehabilitation of maxillary lateral incisors or mandibular lateral and central incisors (Kolinski et al., 2018). At the 1-year follow-up implant survival rate was 96.7%. Marginal bone level changes from insertion to 12 months was -0.25 ± 1.38 mm. Papilla index score and PES improved at the 1-year follow-up. In conclusion, all these above-mentioned studies indicated promising clinical data for NDI in the aesthetic area. Yang et al. examined the success rate of NDI in the maxillary anterior region and that of reimplants at the same site (Yang et al., 2020). Survival and success rates of 1,095 NDI inserted in 835 patients were 96.99% and 96.51% with a mean follow-up time of 17.83 ± 7.61 months. NDI with bone augmentation showed lower failure rates. The success rate of the 23 reimplants was 95.65%. The authors concluded that bone augmentation simultaneously performed during NDIs implantation was favorable for a single missing tooth and that the reimplantation of failed NDI was reliable and stable after successful bone reconstruction.

A recent meta-analysis compared the longevity and marginal bone loss of NDI (⌀ ≤ 3.3-mm) and SDI supporting single crowns (Telles et al., 2019). In the 4 included studies, implant success rate ranged from 93.8% to 100% over a maximum follow-up of 3 years, with no difference between NDI and SDI. Meta-analysis indicated higher bone loss in NDI compared to SDI. When analysis was restricted to RCT, no such difference was present. A 3-year split-mouth randomized clinical

trial compared NDI (⌀ 3.3 mm) to SDI (⌀ 4.1 mm) in the posterior region of the jaws in regard to the marginal bone level and implant and prosthesis survival and success rates (de Souza et al., 2018). At the 3-year follow-up, implant survival rates of 100% were shown for both groups. The implant success rate for SDI was 100%, whereas for NDI was 95%. The prosthesis success rates at 3-year follow-up were 90% for NDI and 95% for SDI. The reasons of prosthesis failures were minor veneer chipping and screws loosening. The authors concluded that NDI inserted to support single crowns in the posterior region did not differ from RDIs in regard to MBL, implant survival, and success rates. Shi et al. investigated in a retrospective cohort study the long-term survival, complications, peri-implant conditions, marginal bone loss, and patient satisfaction of fixed dental prostheses supported by NDI (⌀ 3.3 mm) in the posterior jaw (Shi et al., 2018). The overall implant survival rates were 96.9% at implant level and 97.0% at patient level with a mean follow-up time of 10.1 years. 8.5% of the implants showed signs of peri-implantitis. 89.2% of the patients were satisfied with the esthetics of the restorations, while 84.6% of the patients were satisfied with the function of the restorations.

In our study, Tissue Level implants in the NDI group showed higher survival rates than Bone Level implants in the NDI group. This could be explained on the one hand by the transmucosal location of the microgap in tissue-level implants as it is positioned at a certain distance from the bone crest. On the other hand, Tissue Level implants show mechanical benefits as the critical biomechanical crestal area is located more crestaly to a position, where the tulip-shaped implant has a wider diameter. Therefore, a more stable crestal part of the implant and a shorter technical implant-crown ratio is existing.

In our study, the up-to-date and the postoperative radiograph were compared to analyze the distance from the implant-abutment periphery to the apex of the implant as described before (Schiegnitz et al., 2016). As panoramic and intraoral radiographs were used to determine the bony situation, a bias is possible and has to be kept in mind, when evaluating these results. However, this method seems to be reliable for this purpose (Kullman et al., 2007; Zechner et al., 2003).

The results of our study showed comparable oral health-related quality of life in both groups after the treatment. These results include a high risk of bias as they were raised retrospectively and there has been some concern that the short-form OHIP-14 may not detect improvements following clinical intervention due to floor effects (Stewart et al., 1988). The OHIP was applied as a tool because it showed high test-retest reliability and was confirmed in numerous cross-sectional population studies (Schiegnitz et al., 2017; Yuen & Nelson, 2014). In the international literature, a retrospective cohort study with a mean follow-up time of 120 months confirmed high long-term survival rates and high patient satisfaction for 3.3 mm NDI (Shi et al., 2017).

5 | CONCLUSION

Within the limitations of this retrospective study, the results demonstrated high survival, success, and patient satisfaction rates after 38 and 42 months for both NDI, inserted in pristine bone and SDI, inserted in horizontally augmented bone. Therefore, both treatment concepts are a safe and predictable procedure for horizontally deficient alveolar ridges.

CONFLICT OF INTEREST

Dr. Schiegnitz reports Grants and Personal fees from Dentsply, personal fees from Geistlich, personal fees from Sanofi-Aventis, personal fees from Septodont, grants and personal fees from Straumann, grants and personal fees from ITI Foundation, personal fees from Mectron, personal fees from Osteology Foundation, outside the submitted work. Dr. Kämmerer reports Grants and Personal fees from 3M Espe, personal fees from Geistlich, personal fees from Medartis, personal fees from Nobel Biocare, grants and personal fees from Straumann, grants from Sanofi-Aventis, grants and personal fees from ITI Foundation, outside the submitted work. Dr. Hellwich has nothing to disclose. Dr. König has nothing to disclose. Dr. Sagheb reports Personal fees from Denstply, personal fees from Geistlich, grants and personal fees from Straumann, outside the submitted work. Dr. Al-Nawas reports Grants and Personal fees from Dentsply, personal fees from Geistlich, personal fees from Sanofi-Aventis, personal fees from Septodont, grants and personal fees from Straumann, grants from ITI Foundation, personal fees from Mectron, grants and personal fees from Camlog, personal fees from Medartis, personal fees from Zimmer, from Osteology Foundation, outside the submitted work.

AUTHOR CONTRIBUTIONS

Kämmerer, PD Dr. Dr. Peer W. Department of Oral and Maxillofacial Surgery, Plastic Surgery, University Medical Centre of the Johannes Gutenberg-University, Germany. Hellwich, Phiipp. Department of Oral and Maxillofacial Surgery, Plastic Surgery, University Medical Centre of the Johannes Gutenberg-University, Germany. König, Dr. Jochem. Institute of Medical Biometry, Epidemiology and Informatics, Johannes Gutenberg-University, Germany. Sagheb, PD Dr. Dr. Keyvan. Department of Oral and Maxillofacial Surgery, Plastic Surgery, University Medical Centre of the Johannes Gutenberg-University, Germany. Al-Nawas, Prof. Dr. Dr. Bilal. Department of Oral and Maxillofacial Surgery, Plastic Surgery, University Medical Centre of the Johannes Gutenberg-University, Germany.

ETHICAL APPROVAL

Ethical approval was obtained from the ethical committee of Rhineland-Palatinate, Germany (Registration number: 2019–14414, Landesärztekammer Rheinland-Pfalz).

DATA AVAILABILITY STATEMENT

The authors confirm that the data supporting the findings of this study are available within the article.

ORCID

Eik Schiegnitz https://orcid.org/0000-0003-1859-943X
Bilal Al-Nawas https://orcid.org/0000-0002-8665-5803

REFERENCES

Albrektsson, T., Zarb, G., Worthington, P., & Eriksson, A. R. (1986). The long-term efficacy of currently used dental implants: A review and proposed criteria of success. *International Journal of Oral and Maxillofacial Implants*, *1*(1), 11–25.

Al-Nawas, B., & Schiegnitz, E. (2014). Augmentation procedures using bone substitute materials or autogenous bone - a systematic review and meta-analysis. *European Journal of Oral Implantology*, *7*(Suppl 2), S219–234.

Berglundh, T., Armitage, G., Araujo, M. G., Avila-Ortiz, G., Blanco, J., Camargo, P. M., Chen, S., Cochran, D., Derks, J., Figuero, E., Hämmerle, C. H. F., Heitz-Mayfield, L. J. A., Huynh-Ba, G., Iacono, V., Koo, K.-T., Lambert, F., McCauley, L., Quirynen, M., Renvert, S., … Zitzmann, N. (2018). Peri-implant diseases and conditions: Consensus report of workgroup 4 of the 2017 world workshop on the classification of periodontal and peri-implant diseases and conditions. *Journal of Clinical Periodontology*, *45*(Suppl 20), S286–S291.

Buser, D., Bragger, U., Lang, N. P., & Nyman, S. (1990). Regeneration and enlargement of jaw bone using guided tissue regeneration. *Clinical Oral Implants Research*, *1*(1), 22–32.

Buser, D., Weber, H. P., & Lang, N. P. (1990). Tissue integration of non-submerged implants. 1-year results of a prospective study with 100 ITI hollow-cylinder and hollow-screw implants. *Clinical Oral Implants Research*, *1*(1), 33–40.

Chappuis, V., Avila-Ortiz, G., Araujo, M. G., & Monje, A. (2018). Medication-related dental implant failure: Systematic review and meta-analysis. *Clinical Oral Implants Research*, *29*(Suppl 16), 55–68. https://doi.org/10.1111/clr.13137

Cinel, S., Celik, E., Sagirkaya, E., & Sahin, O. (2018). Experimental evaluation of stress distribution with narrow diameter implants: A finite element analysis. *Journal of Prosthetic Dentistry*, *119*(3), 417–425. https://doi.org/10.1016/j.prosdent.2017.04.024

Corcuera-Flores, J. R., Perez-Fierro, M., Blanco-Carrion, A., Torres-Lagares, D., Castellanos-Cosano, L., & Machuca-Portillo, G. (2020). Bone loss around narrow implants versus standard diameter implants: Retrospective 2-years case-control study. *Journal of Clinical and Experimental Dentistry*, *12*(1), e79–e84. https://doi.org/10.4317/medoral.56422

de Souza, A. B., Sukekava, F., Tolentino, L., Cesar-Neto, J. B., Garcez-Filho, J., & Araujo, M. G. (2018). Narrow- and regular-diameter implants in the posterior region of the jaws to support single crowns: A 3-year split-mouth randomized clinical trial. *Clinical Oral Implants Research*, *29*(1), 100–107. https://doi.org/10.1111/clr.13076

Ding, X., Zhu, X. H., Liao, S. H., Zhang, X. H., & Chen, H. (2009). Implant-bone interface stress distribution in immediately loaded implants of different diameters: A three-dimensional finite element analysis. *Journal of Prosthodontics*, *18*(5), 393–402. https://doi.org/10.1111/j.1532-849X.2009.00453.x

Elsyad, M. A. (2016). Patient satisfaction and prosthetic aspects with mini-implants retained mandibular overdentures. A 5-year prospective study. *Clinical Oral Implants Research*, *27*(7), 926–933. https://doi.org/10.1111/clr.12660S

Enkling, N., Saftig, M., Worni, A., Mericske-Stern, R., & Schimmel, M. (2017). Chewing efficiency, bite force and oral health-related quality of life with narrow diameter implants–a prospective clinical study: Results after one year. *Clinical Oral Implants Research*, *28*(4), 476–482. https://doi.org/10.1111/clr.12822

Ghazal, S. S., Huynh-Ba, G., Aghaloo, T., Dibart, S., Froum, S., O'Neal, R., & Cochran, D. (2019). A Randomized, controlled, multicenter clinical study evaluating the crestal bone level change of SLActive bone level O 3.3 mm Implants compared to SLActive bone level O 4.1 mm implants for single-tooth replacement. *International Journal of Oral and Maxillofacial Implants*, *34*(3), 708–718. https://doi.org/10.11607/jomi.6927

John, M. T., Patrick, D. L., & Slade, G. D. (2002). The German version of the oral health impact profile–translation and psychometric properties. *European Journal of Oral Sciences*, *110*(6), 425–433.

Jung, R. E., Al-Nawas, B., Araujo, M., Avila-Ortiz, G., Barter, S., Brodala, N., Chappuis, V., Chen, B. O., De Souza, A., Almeida, R. F., Fickl, S., Finelle, G., Ganeles, J., Gholami, H., Hammerle, C., Jensen, S., Jokstad, A., Katsuyama, H., Kleinheinz, J., … Windisch, P. (2018). Group 1 ITI consensus report: The influence of implant length and design and medications on clinical and patient-reported outcomes. *Clinical Oral Implants Research*, *29*(Suppl 16), 69–77. https://doi.org/10.1111/clr.13342

Katafuchi, M., Weinstein, B. F., Leroux, B. G., Chen, Y. W., & Daubert, D. M. (2018). Restoration contour is a risk indicator for peri-implantitis: A cross-sectional radiographic analysis. *Journal of Clinical Periodontology*, *45*(2), 225–232. https://doi.org/10.1111/jcpe.12829

Klein, M. O., Schiegnitz, E., & Al-Nawas, B. (2014). Systematic review on success of narrow-diameter dental implants. *International Journal of Oral and Maxillofacial Implants*, *29*(Suppl), 43–54. https://doi.org/10.11607/jomi.2014suppl.g1.3

Kolinski, M., Hess, P., Leziy, S., Friberg, B., Bellucci, G., Trisciuoglio, D., Wagner, W., Moergel, M., Pozzi, A., Wiltfang, J., Behrens, E., Zechner, W., Vasak, C., & Weigl, P. (2018). Immediate provisionalization in the esthetic zone: 1-year interim results from a prospective single-cohort multicenter study evaluating 3.0-mm-diameter tapered implants. *Clinical Oral Investigations*, *22*(6), 2299–2308. https://doi.org/10.1007/s00784-017-2329-2

Kullman, L., Al-Asfour, A., Zetterqvist, L., & Andersson, L. (2007). Comparison of radiographic bone height assessments in panoramic and intraoral radiographs of implant patients. *International Journal of Oral and Maxillofacial Implants*, *22*(1), 96–100.

Mombelli, A., van Oosten, M. A., Schurch, E. Jr, & Land, N. P. (1987). The microbiota associated with successful or failing osseointegrated titanium implants. *Oral Microbiology and Immunology*, *2*(4), 145–151.

Monje, A., Chappuis, V., Monje, F., Munoz, F., Wang, H. L., Urban, I. A., & Buser, D. (2019). The critical peri-implant buccal bone wall thickness revisited: An experimental study in the beagle dog. *International Journal of Oral and Maxillofacial Implants*, *34*(6), 1328–1336. https://doi.org/10.11607/jomi.7657

Moy, P. K., & Aghaloo, T. (2019). Risk factors in bone augmentation procedures. *Periodontology 2000*, *81*(1), 76–90. https://doi.org/10.1111/prd.12285

Park, J.-H., Shin, S.-W., & Lee, J.-Y. (2019). Bar versus ball attachments for maxillary four-implant retained overdentures: A randomized controlled trial. *Clinical Oral Implants Research*, *30*(11), 1076–1084. https://doi.org/10.1111/clr.13521

Peron, C., & Romanos, G. (2020). immediate provisionalization of single narrow implants in fresh extraction sockets and healed sites: Clinical and radiographic outcomes of 2 Years Follow-up. *The International Journal of Periodontics & Restorative Dentistry*, *40*(3), 417–424. https://doi.org/10.11607/prd.4622

Preoteasa, E., Imre, M., & Preoteasa, C. T. (2014). A 3-year follow-up study of overdentures retained by mini-dental implants. *International Journal of Oral and Maxillofacial Implants*, *29*(5), 1170–1176. https://doi.org/10.11607/jomi.3222

Roccuzzo, A., Imber, J. C., & Jensen, S. S. (2021). Need for lateral bone augmentation at two narrow-diameter implants: A prospective, controlled, clinical study. *Clinical Oral Implants Research*, *32*(4), 511–520. https://doi.org/10.1111/clr.13721

Sagheb, K., Schiegnitz, E., Moergel, M., Walter, C., Al-Nawas, B., & Wagner, W. (2017). Clinical outcome of alveolar ridge augmentation with individualized CAD-CAM-produced titanium mesh. *International Journal of Implant Dentistry*, *3*(1), 36. https://doi.org/10.1186/s40729-017-0097-z

Schiegnitz, E., & Al-Nawas, B. (2018). Narrow-diameter implants: A systematic review and meta-analysis. *Clinical Oral Implants Research*, *29*(Suppl 16), 21–40. https://doi.org/10.1111/clr.13272

Schiegnitz, E., Al-Nawas, B., Kämmerer, P. W., & Grötz, K. A. (2014). Oral rehabilitation with dental implants in irradiated patients: A meta-analysis on implant survival. *Clinical Oral Investigations*, *18*(3), 687–698. https://doi.org/10.1007/s00784-013-1134-9

Schiegnitz, E., Al-Nawas, B., Tegner, A., Sagheb, K., Berres, M., Kammerer, P. W., & Wagner, W. (2016). Clinical and radiological long-term outcome of a tapered implant system with special emphasis on the influence of augmentation procedures. *Clinical Implant Dentistry and Related Research*, *18*(4), 810–820. https://doi.org/10.1111/cid.12338

Schiegnitz, E., Kammerer, P. W., Sagheb, K., Wendt, A. J., Pabst, A., Al-Nawas, B., & Klein, M. O. (2017). Impact of maxillary sinus augmentation on oral health-related quality of life. *International Journal of Implant Dentistry*, *3*(1), 10. https://doi.org/10.1186/s40729-017-0072-8

Shi, J. Y., Xu, F. Y., Zhuang, L. F., Gu, Y. X., Qiao, S. C., & Lai, H. C. (2017). Long-term outcomes of narrow diameter implants in posterior jaws: A retrospective study with at least 8-year follow-up. *Clinical Oral Implants Research*, *29*(1), 76–81. https://doi.org/10.1111/clr.13046

Shi, J. Y., Xu, F. Y., Zhuang, L. F., Gu, Y. X., Qiao, S. C., & Lai, H. C. (2018). Long-term outcomes of narrow diameter implants in posterior jaws: A retrospective study with at least 8-year follow-up. *Clinical Oral Implants Research*, *29*(1), 76–81. https://doi.org/10.1111/clr.13046

Spray, J. R., Black, C. G., Morris, H. F., & Ochi, S. (2000). The influence of bone thickness on facial marginal bone response: Stage 1 placement through stage 2 uncovering. *Annals of Periodontology*, *5*(1), 119–128. https://doi.org/10.1902/annals.2000.5.1.119

Starch-Jensen, T., & Becktor, J. P. (2019). Maxillary alveolar ridge expansion with split-crest technique compared with lateral ridge augmentation with autogenous bone block graft: A systematic review. *Journal of Oral and Maxillofacial Research es*, *10*(4), e2. https://doi.org/10.5037/jomr.2019.10402

Stewart, A. L., Hays, R. D., & Ware, J. E. Jr (1988). The MOS short-form general health survey. Reliability and validity in a patient population. *Medical Care*, *26*(7), 724–735.

Telles, L. H., Portella, F. F., & Rivaldo, E. G. (2019). Longevity and marginal bone loss of narrow-diameter implants supporting single crowns: A systematic review. *PLoS One*, *14*(11), e0225046. https://doi.org/10.1371/journal.pone.0225046

Trbakovic, A., Bongenhielm, U., & Thor, A. (2018). A clinical and radiological long-term follow-up study of narrow diameter implants in the aesthetic area. *Clinical Implant Dentistry and Related Research*, *20*(4), 598–605. https://doi.org/10.1111/cid.12627

Walter, C., Al-Nawas, B., Wolff, T., Schiegnitz, E., & Grotz, K. A. (2016). Dental implants in patients treated with antiresorptive medication–a systematic literature review. *International Journal of Implant Dentistry*, *2*(1), 9. https://doi.org/10.1186/s40729-016-0041-7D

Yang, G., Chen, L., Gao, Y., Liu, H., Dong, H., & Mou, Y. (2020). Risk factors and reoperative survival rate of failed narrow-diameter implants in the maxillary anterior region. *Clinical Implant Dentistry and Related Research*, *22*(1), 29–41. https://doi.org/10.1111/cid.12867

Yuen, H. K., & Nelson, S. L. (2014). Test–retest reliability of oral health impact profile (OHIP-49) in adults with systemic sclerosis. *Special Care in Dentistry*, *34*(1), 27–33. https://doi.org/10.1111/scd.12036

Zechner, W., Watzak, G., Gahleitner, A., Busenlechner, D., Tepper, G., & Watzek, G. (2003). Rotational panoramic versus intraoral rectangular radiographs for evaluation of peri-implant bone loss in the anterior atrophic mandible. *International Journal of Oral and Maxillofacial Implants*, *18*(6), 873–878.

How to cite this article: Schiegnitz, E., Kämmerer, P. W., Hellwich, P., König, J., Sagheb, K., & Al-Nawas, B. (2021). Treatment concepts of horizontally deficient ridges—A retrospective study comparing narrow-diameter implants in pristine bone with standard-diameter implants in augmented bone. *Clinical Oral Implants Research*, 32, 1159–1167. https://doi.org/10.1111/clr.13807