The Clinical Performance of Narrow Diameter Implants Versus Regular Diameter Implants: A Meta-Analysis

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The purpose of this study is to analyze 1- and 3-year clinical performances of narrow diameter implants (NDIs) versus regular diameter implants (RDIs). A search of electronic databases and a manual search was performed for the time period January 2000 to April 2018. A meta-regression was used to evaluate the effects of the "fixed effects" model on the implant survival rates, prosthesis success rates and marginal bone loss (MBL) with follow-up time of 1 year and 3 years. Of the 11 studies included, the overall combined 1-year implant survival rates were 98.14% for NDIs and 98.20% for RDIs. The overall combined 3-year implant survival rates were 98.71% for NDIs and 98.84% for RDIs. The corresponding values for 1-year prosthesis success rates were 96.94% for NDIs and 99.25% for RDIs. The corresponding values for 3-year prosthesis success rates were 89.25% for NDIs and 96.55% for RDIs. The meta-regression showed no significant differences between NDIs and RDIs regarding implant survival rates, prosthesis success rates, and MBL in 1-year and 3-year follow-up ($P > .05$). The results of this meta-analysis concluded that the implant diameter did not affect its survival rates, prosthesis success rates, and MBL in 1 and 3 years. The use of NDIs instead of bone augmentation procedures with RDIs did not affect its survival rates, prosthesis success rates, and MBL in the short-term and middle-term. However, more high-quality randomized controlled trials and long follow-up studies are needed on this topic.

Key Words: narrow diameter implants, regular diameter implants, implant survival rates, prosthesis success rates, marginal bone loss

INTRODUCTION

The use of dental implants has been confined to areas with adequate bone volume.[1] Many patients have reduced mesiodistal space,[2] crestal bone width,[3] amounts of interradicular space.[4–7] Use of narrow diameter implants (NDIs) can avoid extensive bone augmentation procedures and reduce the surgical complexity. Implants with diameters of 3.0 mm or greater and less than 3.75 mm (3.0 mm $\leq$ diameter $<$ 3.75mm) have been considered to be NDIs.[8] Implants with diameters of 3.75 mm or greater and less than 5 mm (3.75 mm $\leq$ diameter $<$ 5 mm) have been considered to be regular diameter implants (RDIs).[8] Compared to RDIs, NDIs have reduced contact areas with the bone. Whether the clinical performance of NDIs performs as well as RDIs is still controversial.

There are systematic reviews that have evaluated the clinical outcomes of NDIs[1,9,10] or the role of implant diameter on dental implants survival rates.[11–13] However, their designs all had some limitations, such as lack of high quality randomized controlled trial (RCT) research. In addition, the NDIs group and the RDIs were from different research. Moreover, the clinical performances for a definite time were not evaluated.

The purpose of this study was to perform a meta-analysis to assess the clinical performances of NDIs and RDIs. The population (P) was patients who had received NDIs (experimental group [I]) and RDIs (control group [C]). Outcomes (O) included implant survival rates, prosthesis success rates, and marginal bone loss (MBL). This systematic review was conducted to answer the following questions: (1) Do survival rates differ between NDIs and RDIs? (2) Do prosthesis success rates differ between NDIs and RDIs? (3) Does MBL differ between NDIs and RDIs.

MATERIALS AND METHODS

Protocol

This meta-analysis was performed according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) checklist described by Moher et al.[14]

Eligibility criteria

The reference lists of all retrieved articles were studied for further identification of potentially relevant studies using the inclusion and exclusion criteria.

Inclusion criteria

Studies were included with the following characteristics: (1) RCTs, clinical cohort trials, and observational studies; (2) human studies; (3) articles that had more than five implants in each group; and (4) article that had at least 1-year follow-up.

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Exclusion criteria

Trials with the following characteristics were excluded: (1) articles containing duplicate reports of earlier trials, (2) articles where the authors were unable to acquire full texts, (3) animal studies, (4) in vitro experiments, (5) computer simulations, and (6) reviews.

Information sources

A search of electronic databases included PUBMED, EMBASE, and the Cochrane Central Register of Controlled Trials from January 2000 until April 2018. A manual search for relevant studies published in dental journals was conducted for the same time period. The dental journals included were as follows: *Journal of Clinical Periodontology*, *Clinical Oral Implants Research*, *Journal of Oral and Maxillofacial Implants, Implant Dentistry, Journal of Oral Implantology, Journal of Oral and Maxillofacial Surgery, Journal of Dental Research, Journal of Prosthetic Dentistry, Journal of Periodontology, International Journal of Periodontics & Restorative Dentistry, International Journal of Oral & Maxillofacial Surgery, Clinical Implant Dentistry and Related Research*, and *European Journal of Oral Implantology*.

Research strategy

The search was performed by two examiners (M.M., Q.M.). The authors used the guidelines of the Cochrane Collaboration to identify trials. The following search terms and different combinations of medical subject heading (MeSH) terms and textual words were used: "dental implants," "dental implantation," "narrow diameter," and "regular diameter."

Study selection

Two examiners (M.M., Q.M.) independently screened the titles and the abstracts of the studies and classified them according to the inclusion and exclusion criteria. Any disagreements were settled through the participation of a third author (H.L.).

Data collection

Two investigators (M.M., M.Q.) independently extracted study characteristics and data from the included articles. Elements of interest for each study included first author name, year of publication, country of origin of the author, study design, total number of patients and groups, implant type, inclusion and exclusion criteria, follow-up duration, and study outcomes. Study outcomes included survival rates, prosthesis success rates (which were defined as without prosthetic complications [eg, porcelain fracture, abutment screw loosening, abutment fracture, veneer chipping]), and MBL. In case of a discrepancy, a third author (H.L.) participated in the discussion until a consensus was achieved. Discrepancies between the reviewers were resolved by discussion and consensus with a third author participated.

Risk of bias in individual studies

Two investigators (M.M., M.Q.) used the Newcastle-Ottawa Scale to assess the methodological quality of the retrospective studies.[15] The scale ranges from 0 to 10 with a score above 5 considered high quality. The Jadad scale was used to assess the methodological quality of the randomized controlled trials.[16] The scale ranges from 0 to 5 with a score above 3 considered high quality.

Summary measures

Patient demographics outcomes were gathered and analyzed. Review Manager version 5.3.5 (Cochrane Collaboration, Oxford, UK) was used for meta-analysis. Risk ratio (RR) was assessed for dichotomous outcomes and weighted mean differences (WMD) for continuous outcomes with 95% confidence intervals (CI). A P value of .05 was set as the significant level.

Synthesis of results

Heterogeneity was assessed using the χ^2 test and I^2 statistics, where I^2 was used to estimate the percentage of error resulted from the across-study variations. If the $P > .05$ was presented in an analysis, we considered the preform fixed-effects model as the homogeneity of studies was satisfactory. Otherwise, the random-effects model was chosen. Sensitivity analysis was achieved by adjusting the assumptions involved in the meta-analysis and by single removal of the studies. Funnel plots were assessed by graphic demonstration to determine publication bias.

Results

Literatures selection and characteristics

A total of 367 potential articles were identified from the literature search strategy: 176 articles were assessed by title and abstract and then 27 articles were subsequently assessed by full text after exclusion of 149 reports. A total of 11 articles were finally included in this meta-analysis according to the inclusion and exclusion criteria. There were 2 RCTs and 9 observational articles included in this analysis (Figure 1). The follow-up time ranged from 12 to 120 months. The characteristics of the included studies are summarized in Table 1. Table 2 shows information extracts related to implants of all the included studies.

Risk of bias within studies

Table 1 shows the methodological quality assessment of the studies. Of the nine observational articles, three had an Newcastle-Ottawa Scale (NOS) score of 6, five had an NOS score of 7, and one had an NOS score of 9. The two RCTs both had a Jadad scale score of 3. The results showed that all the studies were high quality.

Comparison of the 1-year implant survival rates

The 1-year implant survival rates were documented in 11 trials.[4,17–27] There were no heterogeneities in the groups ($I^2 = 0\%$; Figure 2). We used fixed-effects model for the analysis. The overall pooled 1-year implant survival rates were 98.14% for NDIs and 98.20% for RDIs, and found the 1-year implant survival rates of NDIs group was lower than RDIs group (RR, 0.99; 95% CI, 0.98, 1.00; $I^2 = 0\%$; $P = .17$). No significant difference between the NDI group and RDI group was found in implant survival rates with follow-up time of 1 year.

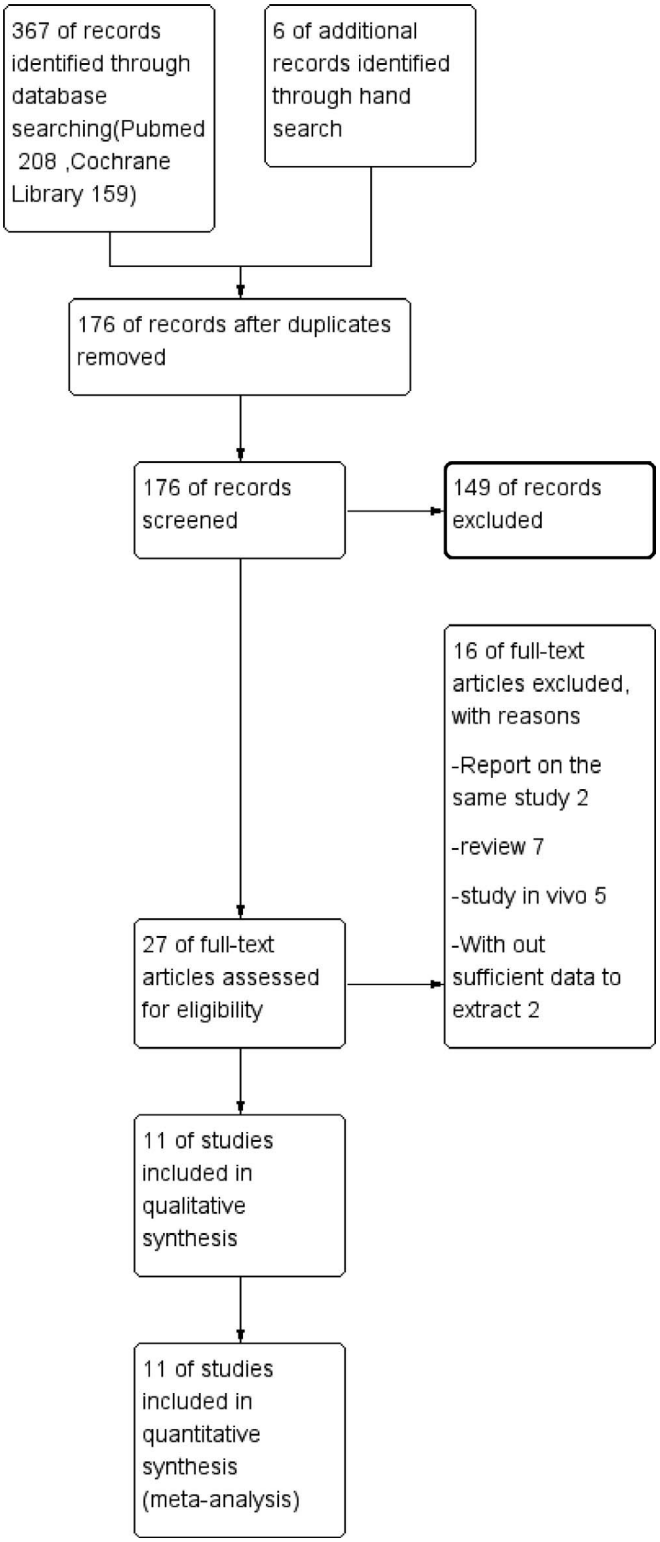


Figure 1. Flowchart showing results of literature search.

Comparison of the 3-year implant survival rates

The 3-year implant survival rates were reported in 8 studies.[4,17,18,21,22,24,26,27] There were no significant heterogeneities in the groups ($I^2 = 0\%$; Figure 3). A fixed-effects model was used in the analysis. The overall combined 3-year implant survival rates were 98.71% for NDIs and 98.84% for RDIs, and the 3-year implant survival rates of the NDI group was lower than the RDI group (RR, 0.98; 95% CI, 0.96, 1.00; $I^2 = 0\%$; $P = .13$) and no significant difference between the NDI group and the RDI group was found in implant survival rates with follow-up time of 3 years.

Comparison of the 1-year prosthesis success rates

The differences in 1-year prosthesis success rates between the two groups are shown in Figure 4. There were 4 studies[4,21,26,27] evaluated for the 1-year prosthesis success rates. There were no heterogeneities in the groups ($I^2 = 0\%$). A fixed-effects model was used in the analysis. The corresponding values for 1-year prosthesis success rates were 96.94% for NDIs and 99.25% for RDIs, and the 1-year prosthesis success rates of the NDI group was lower than the RDI group (RR, 0.98; 95% CI, 0.91, 1.04; $I^2 = 0\%$; $P = .48$). No significant difference between the NDI group and the RDI group was found in prosthesis success rates with follow-up time of 1 year.

Comparison of the 3-year prosthesis success rates

The 3-year prosthesis success rates between the two groups were reported in 4 studies.[4,21,26,27] There were no heterogeneities in the groups ($I^2 = 0\%$; Figure 5). A fixed-effects model was used for the analysis. The corresponding values for 3-year prosthesis success rates were 89.25% for NDIs and 96.55% for RDIs, and the 3-year prosthesis success rates of the NDI group was lower than the RDI group (RR, 0.98; 95% CI, 0.87, 1.11; $I^2 = 0\%$; $P = .78$). There was no significant difference between the NDI group and the RDI group in prosthesis success rates with follow-up time of 3 years.

Comparison of the 1-year MBL

The 1-year MBL between the two groups was assessed in 3 study trials.[4,22,27] There were no heterogeneities in the groups ($I^2 = 0\%$; Figure 6). A fixed-effects model was used for the analysis, and found the 1-year MBL of the NDI group was approximately what the RDI group was (standard mean difference [SMD], −0.02; 95% CI, −0.35, 0.31; $I^2 = 0\%$; $P = .91$). No significant difference between the NDI group and the RDI group was found in MBL for follow-up time of 1 year.

Comparison of the 3-year marginal bone loss

The 3-year MBL between the two groups was evaluated in 8 trials in 3 studies.[4,22,27] There were no heterogeneities in the groups ($I^2 = 0\%$; Figure 7). A fixed-effects model was used for the analysis, and found the 1-year MBL of the NDI group was approximately what the RDI group was (SMD, 0.16; 95% CI, −0.19, 0.52; $I^2 = 0\%$; $P = .37$). No significant difference between NDIs group and RDIs group was found in MBL for follow-up time of 3 years.

Discussion

NDIs and RDIs for clinical performance, load-bearing capacity, and long-term outcome are still controversial. At least 1 mm of

TABLE 1

Characteristics and quality assessment of the included studies*

Study	Country	Implant System	Sample Size		Follow-Up (mo)	Implant Position	Study Type	NOS Score	Jadad Scale Score
			NDIs	RDIs					
Andersen et al[4]	Norway	3i	32	28	36	Anterior	RS	7	—
Garlini et al[17]	Italy	3i	11	470	60	Anterior posterior	RS	6	—
Romeo et al[18]	Italy	Straumann	122	208	84	Anterior posterior	RS	7	—
Olate et al[19]	Brazil	Neodent	137	1217	12	Anterior posterior	RS	6	—
Mijiritsky et al[20]	Israel	Alon Tavor	113	2794	28	Anterior posterior	RS	7	—
Mangano et al[21]	Italy	Leone System	5	121	120	Posterior	RS	7	—
Zweers et al[22]	The Netherlands	Straumann	75	44	36	Anterior posterior	RS	9	—
Benic,[23] Ioannidis et al[24]	Switzerland	Straumann Bone Level	20	20	36	Anterior posterior	RCT	—	3
Herrmann et al[25]	Germany	Straumann	154	396	24	Anterior posterior	RS	6	—
Nilsson et al[26]	Sweden	Straumann Bone Level	41	7	60	Anterior	RS	7	—
de Souza et al[27]	USA	Straumann Tissue Level	22	22	36	Posterior	RCT	—	3

*NDIs indicate narrow diameter implants; RDIs, regular diameter implants; NOS, Newcastle-Ottawa Scale; RS, retrospective study; RCT, randomized controlled trial.

residual bone is needed from buccal, oral bone, and adjacent teeth to the dental implants. The width of residual bone from labial bone to dental implants is at least 2 mm for aesthetics, particularly for anterior teeth. At least 6 mm width of residual bone is necessary for RDIs. It is common in clinical practice that the mesiodistal space, as well as the horizontal alveolar ridge width, is sometimes too small. Surgical techniques like expansion with osteotomes, guided bone regeneration, autologous bone grafts, crestal expansion techniques, and osteogenic distraction allow us to increase the available bone space, but sometimes with complications.[28] NDIs were developed to offer relatively simple implant solutions in bone-deficient ridges to avoid complex bone augmentation.[29,30] For all of the 11 included studies, NDIs were used in either the anterior or the posterior area, each in 9 studies. We found that the failure rates of NDIs in all the studies and areas in this review were low. Eleven studies reported 1-year implant survival rates, and 9 studies reported 3-year implant survival rates. There was no significant difference between NDIs and RDIs in terms of 1-year and 3-year implant survival rates.

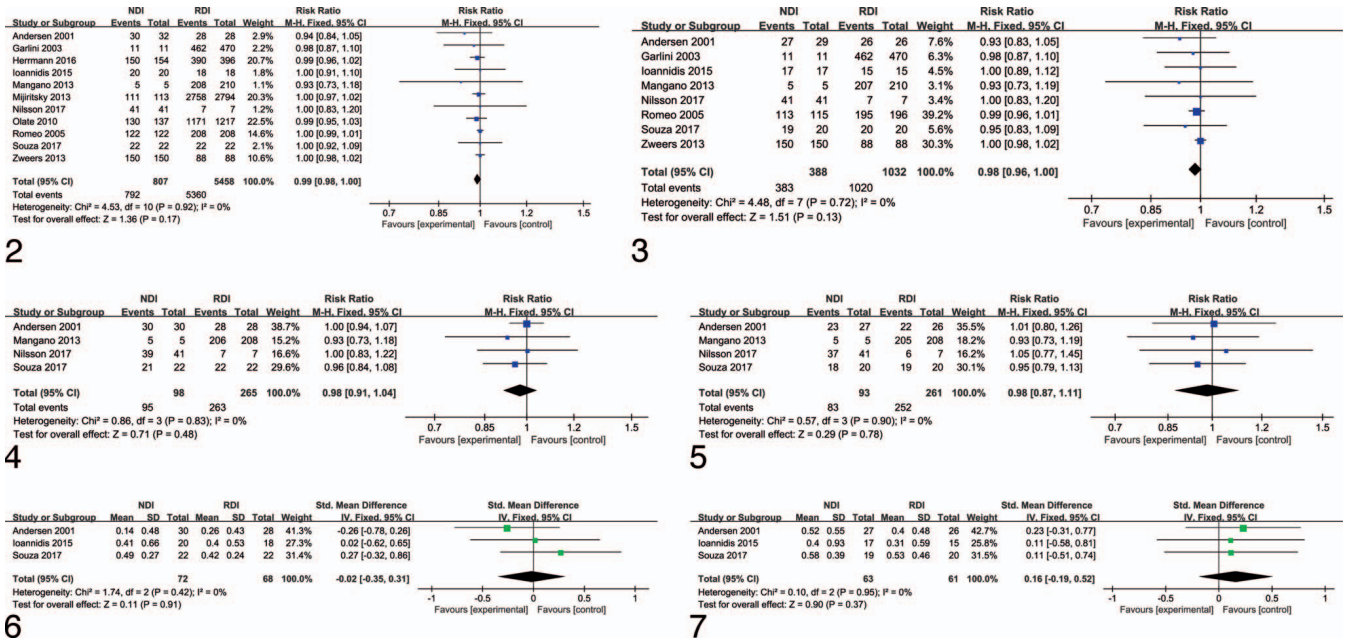
Some scholars were concerned about the potential biomechanical risk factors for the use of NDIs. Narrow diameter dental implants and abutments were more prone to fatigue fracture than the larger diameter with in vitro study.[31,32] However, to

TABLE 2

Data extract of the included studies*

Study		1-Year Implant Survival			3-Year Implant Survival			1-Year Prosthesis Success			3-Year Prosthesis Success			1-Year Marginal Bone Level			3-Year Marginal Bone Level		
		No. of Surviving Implants	Total	Implant Survival Rate, %	No. of Surviving Implants	Total	Implant Survival Rate, %	No. of Successful Prostheses	Total	Prosthesis Success Rate, %	No. of Successful Prostheses	Total	Prosthesis Success Rate, %	Mean	SD	Total	Mean	SD	Total
Andersen et al[4]	NDIs	30	32	93.75	27	29	93.10	30	30	100.00	23	27	85.19	0.14	0.48	30	0.52	0.55	27
	RDIs	28	28	100.00	26	26	100.00	28	28	100.00	22	26	84.62	0.26	0.43	28	0.40	0.48	26
Garlini et al[17]	NDIs	11	11	100.00	11	11	100.00												
	RDIs	462	470	98.30	462	470	98.30												
Romeo et al[18]	NDIs	122	122	100.00	113	115	98.26												
	RDIs	208	208	100.00	195	196	99.49												
Olate et al[19]	NDIs	130	137	94.89															
	RDIs	1171	1217	96.22															
Mijiritsky et al[20]	NDIs	111	113	98.23															
	RDIs	2758	2794	98.71															
Mangano et al[21]	NDIs	5	5	100.00	5	5	100.00	5	5	100.00	5	5	100.00						
	RDIs	208	210	99.05	207	210	98.57	206	208	99.04	205	208	98.56						
Zweers et al[22]	NDIs	150	150	100.00	150	150	100.00												
	RDIs	88	88	100.00	88	88	100.00												
Ioannidis et al[24]	NDIs	20	20	100.00	17	17	100.00							0.41	0.66	20	0.40	0.93	17
	RDIs	18	18	100.00	15	15	100.00							0.40	0.53	18	0.31	0.59	15
Herrmann et al[25]	NDIs	150	154	97.40															
	RDIs	390	396	98.48															
Nilsson et al[26]	NDIs	41	41	100.00	41	41	100.00	39	41	95.12	37	41	90.24						
	RDIs	7	7	100.00	7	7	100.00	7	7	100.00	6	7	85.71						
de Souza et al[27]	NDIs	22	22	100.00	19	20	95.00	21	22	95.45	18	20	90.00	0.49	0.27	22	0.58	0.39	19
	RDIs	22	22	100.00	20	20	100.00	22	22	100.00	19	20	95.00	0.42	0.24	22	0.53	0.46	20

*NDIs, indicates narrow diameter implants; RDIs, regular diameter implants; SD, standard deviation.



Figures 2–7. Figure 2. Forest plot showing 1-year implant survival rates in the two groups. **Figure 3.** Forest plot showing 3-year implant survival rates in the two groups. **Figure 4.** Forest plot showing 1-year prosthesis success rates in the two groups. **Figure 5.** Forest plot showing 3-year prosthesis success rates in the two groups. **Figure 6.** Forest plot showing 1-year marginal bone loss in the two groups. **Figure 7.** Forest plot showing 3-year marginal bone loss in the two groups.

raise NDIs' mechanical properties, alloys were used instead of commercially pure titanium. The most common alloy used was Ti-6Al-4V. However, Ti-6Al-4V performed worse than commercially pure titanium in biocompatibility according to in vitro and animal studies.[33] Recently, titanium-zirconium alloy (Ti/Zr≈15%, Zr/≈85%Ti, Roxolid, Straumann AG, Basel, Switzerland) has been introduced into the market.[34,35] Ti-Zr alloy was first applied to Straumann's 3.3-mm diameter implants. Currently, Ti-Zr alloy is available for all diameters in Straumann implants with the SLActive surface. In vitro studies showed that Ti-Zr implant could reach 40% better fatigue stress resistance compared with Ti.[34,36] Ti-Zr implant showed satisfactory osteoconductivity or even better biocompatibility when compared with pure Ti from animal studies. Ti-Zr may become a priority selection when using NDIs.[37] Six of the 11 involved, and most recent, studies used Straumann implants. Four studies with 3 dental implant systems documented 1-year and 3-year prosthesis success rates. There was no significant difference between NDIs and RDIs in terms of prosthetic complications (eg, porcelain fracture, abutment loosening, abutment fracture, veneer chipping) in 1-year and 3-year follow-up. NDIs performs well in biomechanical risk factors in clinical practice.

According to in vitro studies and finite element analyses, NDIs bring about disadvantageous stress peaks at the implant-bone interface because the stress values of the crestal cortical bone are related to the dental implant diameter.[37,38] According to in vitro studies, peri-implant crestal bone resorption may occur as a result of inadequate overloading of NDIs. However, in clinical practice in 3 studies' trials, the meta-analysis found no significant difference between NDIs and RDIs in terms of MBL in 1-year and 3-year follow-up.

In this work, we found that 1-year and 3-year survival rates, prosthesis success rates, and MBL of NDIs were similar to RDIs. This might be a result of newer implant designs and surgical methods adapted to those designs were used, and cases were selected more appropriately. The use of NDIs is expected to decrease the number of continuous augmentation of bone augmentation surgery and the difficulty of implanting for doctors without proper surgery experience.

Conclusion

The results of this meta-analysis showed that there was no significant difference between NDIs and RDIs in terms of 1-year implant survival rates, 3-year implant survival rates, 1-year prosthesis success rates, 3-year prosthesis success rates, 1-year MBL, and 3-year MBL. NDIs are superior to RDIs in avoiding extensive bone augmentation procedures, reducing the surgical complexity, treatment time, and pain. Regardless, NDIs would probably have been considered the alternate of RDIs in clinical situations in which space or bone availability related difficulties in the anterior or posterior area. However, more high-quality, randomized controlled trials are required to confirm whether RDIs are better than NDIs in different indications in the long-term.

Abbreviations

CI: confidence intervals
MBL: marginal bone loss
MeSH: medical subject heading
NDI: narrow diameter implant
NOS: Newcastle-Ottawa Scale
RCT: randomized controlled trial
RDI: regular diameter implant

RR: risk ratio
WMD: weighted mean differences

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Note

The authors declare no conflicts of interest.

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