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Narrow-diameter versus standard-diameter implants placed in horizontally regenerated bone in the rehabilitation of partially and completely edentulous patients: A systematic review

KEY WORDS
horizontal bone augmentation, narrow-diameter implants, review (systematic)

ABSTRACT

Purpose: The present systematic review and meta-analysis aimed to investigate the available evidence in the literature to answer the following focused question: In partially edentulous arches with reduced bone width, do implants placed after horizontal bone augmentation exhibit differences in survival and success rate compared to narrow-diameter implants placed in native bone?

Materials and methods: A population, intervention, comparison and outcome question was defined and an electronic search was conducted using the MEDLINE (via PubMed) and Cochrane Oral Health Group databases to identify all studies analysing the use of standard-diameter implants inserted in regenerated bone or narrow-diameter implants for the rehabilitation of partially or completely edentulous atrophic maxillae and mandibles. Inclusion criteria and quality assessments were established, and studies were selected on this basis.

Results: Twenty-four studies met the inclusion criteria and were analysed cumulatively. A comparative meta-analysis was not possible due to the lack of studies directly comparing the two rehabilitation methods in question. A cumulative implant survival rate of 97.80% (1246/1274; pooled proportion 0.984, 95% confidence interval 0.977–0.991) was reported for the narrow implants placed in atrophic ridges, while similar results were obtained for the standard-diameter implants placed in regenerated bone, with a cumulative implant survival rate of 97.94% (1332/1360; pooled proportion 0.983, 95% confidence interval 0.976–0.990).

Conclusions: The present systematic review found high and comparable survival rates between narrow- and standard-diameter implants placed in regenerated bone; however, well-designed randomised controlled trials are required to support the hypothesis that both treatment strategies are successful in comparable circumstances.

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Introduction

The use of endosseous implants to rehabilitate partially or completely edentulous arches is a treatment method based on a solid foundation of experience and scientific evidence; however, in many patients it is not possible to place 'standard'-diameter implants (SDIs) in cases of extreme horizontal crestal bone resorption. To overcome this restriction, several techniques are currently used to

augment bone horizontally, but although implant surgery alone already requires a skilled operator, augmentation procedures are often more technically demanding than implant placement only and thus require more experienced operators. Moreover, these techniques could imply an increase in cost due to the use of non-autogenous grafts and may increase the risk of morbidity and postoperative complications[1].

Narrow-diameter implants (NDIs) are now commonly available for the rehabilitation of single-tooth gaps with limited mesiodistal space, especially for the replacement of lateral incisors[2] or in case of reduced ridge width to avoid the need for lateral bone augmentation. The use of NDIs for rehabilitation of the posterior regions of the maxilla and mandible is still uncommon, however[3]. Caution is advised when using them as a reduced implant diameter might increase the risk of implant fracture due to the reduced mechanical stability and increased risk of overload[4].

The number of studies on the use of NDIs is limited if compared to the amount of literature about horizontal bone augmentation. Favourable treatment outcomes and high survival rates have been reported[5-7], even when compared with SDIs[8,9]; however, there are no studies comparing NDIs with SDIs placed in lateral regenerated bone, which are their most obvious treatment alternative.

Several types of bone augmentation techniques and biomaterials that can be used to perform the abovementioned procedures have been reported in the literature[10]. The variety of techniques and biomaterials increases the number of variables involved, making comparison of the two therapeutic options more difficult. Different techniques and biomaterials clearly have different characteristics and, of course, potentially different short- and long-term treatment outcomes[11].

Establishing a clear definition of 'narrow' with regard to implant diameter can be difficult since the use of reduced-diameter implants can vary greatly. An NDI positioned in an anterior sector is clearly not subjected to the same biomechanical load as an implant placed in a posterior area, and the same applies to NDIs supporting single crowns and those supporting fixed partial restorations. The very concept of 'narrow' appears to be relative and its definition can change from study to study. Implants with a diameter of 3.75 mm or 3.30 mm are defined as regular or standard in some studies[12,13] and narrow in others[8,14]. The variety of terms used in different studies increases this lack of clarity: in addition to the generic 'narrow', the terms 'mini', 'small' and 'very small' are used for different diameters that very often overlap; as such, what is indicated with a specific definition in one study can be defined differently in another[13,15-18]. The confusion arises primarily from the lack of an accepted consensus that definitively classifies dental implant diameters, but also from differences in the anatomical position of the implant: a 3.30-mm-diameter implant is certainly narrow if placed in a molar position, but would probably not be defined in the same way if placed in a maxillary or mandibular lateral incisor position. For the scope of the present systematic review, the term 'narrow' was applied to all diameters smaller than 3.75 mm, according to a classification based on the terms most frequently used in the literature[19].

The present systematic review aimed to compare the outcomes, particularly in terms of survival and success rate, of NDIs placed in native bone with those of SDIs placed in horizontally regenerated atrophic maxillae and mandibles. Secondary outcomes such as marginal bone loss, biological complications and prosthetic complications were also analysed.

Materials and methods

The present review was registered in the International Prospective Register of Systematic Reviews (PROSPERO; no. CRD42018113089).

Population, intervention, comparison and outcome framework and focused question

The focused question of this systematic review was formatted according to the population, intervention, comparison and outcome (PICO) framework:

- Population: Partially edentulous patients;
- Intervention: Implant placement after horizontal bone augmentation;
- Comparison: NDI placement;
- Outcome: Implant survival/success.

The focused question was as follows: 'In partially edentulous arches with reduced bone width, do implants placed after horizontal bone augmentation exhibit differences in survival and success rate compared to NDIs placed in native bone?'

Search strategy

The data were processed in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines[20]; the introductory set of studies related to the topic 'survival and success rate of NDIs placed in native bone and SDIs placed in horizontally regenerated bone for the fixed rehabilitation of partially edentulous patients' was obtained through an electronic search of the MEDLINE (via PubMed) and Cochrane Oral Health Group databases. A search was conducted of these databases to identify relevant articles published up to 30 March 2020 using the relevant keywords and respective Boolean operators (AND, OR and NOT), using the following strategy: (((((jaw, edentulous, dental implants) OR (partially edentulous) OR (partial edentulism) OR (fully edentulous) OR (full edentulism) OR (reduced width ridge*))) AND (horizontal bone augmentation, horizontal bone graft*, horizontal augmentation*, horizontal ridge augmentation*) AND / OR (dental implants)) OR ((narrow dental implants, narrow implant, narrow diameter implant) OR (native bone, pristine bone))) AND (outcome assessment, treatment outcome, dental implants OR dental implant outcomes OR dental implant failure OR dental implant survival OR dental implant success).

A manual search was conducted of the websites of the following scientific journals: Clinical Implant Dentistry and Related Research, Clinical Oral Investigations, Clinical Oral Implants Research, European Journal of Oral Implantology, European Journal of Prosthodontics and Restorative Dentistry, Journal of Clinical Periodontology, Journal of Cranio-Maxillofacial Surgery, Journal of Dental Research, Journal of Oral Implantology, Journal of Oral Maxillofacial Surgery, Journal of Oral Rehabilitation, Journal of Periodontology, Journal of Prosthetic Dentistry, Implant Dentistry, International Journal of Oral & Maxillofacial Surgery, International Journal of Oral Surgery, International Journal of Periodontics & Restorative Dentistry, International Journal of Oral & Maxillofacial Implants and International Journal of Periodontics and Restorative Dentistry.

Four independent reviewers (NAV, RG, PB and VM) screened the titles and abstracts of the articles obtained. If an abstract was not available on PubMed, it was extracted from the printed article. Based on the selection of abstracts, full-text articles were then obtained. Any disagreements were resolved by discussion. The full texts were then selected according to the inclusion and exclusion criteria by NAV, RG and PB and the selected articles were double-checked by AB, GM and GI.

Inclusion criteria

Studies were included if the following a priori criteria were met:

- prospective cohort human studies, randomised clinical trials;
- retrospective cohort studies;
- follow-up period ≥ 1 year from implant placement;
- ≥ 10 patients;
- data clearly reported about implant diameter;
- data clearly reported about the type of bone augmentation performed and horizontal bone gain;
- outcome data clearly reported for NDIs and for SDIs that received horizontal bone augmentation;
- implants restored with fixed dental restorations.

Exclusion criteria

The exclusion criteria were as follows:

- preclinical studies;
- animal studies;

- case reports and case series;
- articles using the same cohort of patients;
- narrow implants with diameter > 3.75 mm;
- mixed data (narrow implants placed in regenerated sites, different diameters);
- implants used to support removable dentures.

The diameter threshold for defining NDIs was chosen according to the method explained in the Introduction section of the present study and proposed by Al-Johany et al[19] in their classification that considers all diameters smaller than 3.75 mm as "narrow" and further subclassifies diameters smaller than 3.00 mm as "extra narrow".

Quality assessment

Two authors (AB and NAV) independently assessed the studies in terms of the inclusion criteria, relevance, eligibility and risk of bias following the Joanna Briggs Institute Critical Appraisal tool[21]; any disagreement was resolved by consensus between the reviewers and a statistician (PT).

Data extraction and collection process

Following the screening process, five reviewers (NAV, RG, PB, GT and GM) independently extracted the data of the selected articles using data extraction tables. All the extracted data were double-checked and any conflicts were resolved among the authors and the resolution was confirmed by PT. The following information was extracted from the included studies: year of publication, study design, number of patients, number of patients at the end of the study, number of implants, dropouts, mean age of patients, age range of patients, implant diameter, restoration type, type of lateral augmentation, biomaterial used, type of membrane used, cemented or screw-retained restoration, location in the oral cavity, number of implants lost and rate of implant loss, implant success and survival rate, number of biological complications, follow-up (range, mean), location of lost implants, mean bone gain after lateral augmentation and marginal bone loss (MBL) at ≥ 1 year follow-up. Studies reporting data on NDIs and SDIs were included only if the NDI outcomes were clearly distinguishable; otherwise, they were excluded as 'mixed data'.

The primary (implant survival and success rate) and secondary outcomes (MBL, bone graft failure, infection and prosthetic complications) were classified as follows:

- Implant survival: An implant still in function, without mobility but with current or previous history of pain or exudates and MBL > 0.2 mm but measuring less than half the length of the implant body[22].
- Success rate: An implant with no signs of mobility or peri-implant radiolucency, mean vertical bone loss < 0.2 mm after 1 year of function, no persistent pain, discomfort or infection, absence of neuropathies, paraesthesia and violation of vital structures, and patient/dentist satisfaction with the implant-supported restoration[23].
- MBL: Peri-implant bone loss measured after implant restoration as the radiographic distance in millimetres from the implant platform or rough–smooth interface to the most coronal bone–implant contact.
- Bone graft failure: The partial or total loss of the graft, regardless of the cause, or a graft that had to be removed due to infection or non-integration, thus preventing surgical placement of an implant.
- Infections: Abscess, pus, swelling and other signs of peri-implant infection[24].
- Prosthetic complications: Framework fracture, chipping, screw fracture, screw loosening, decementation.

Statistical analysis

Cumulative meta-analyses were performed twice and independently for the two protocols analysed; in particular, the pooled proportion (PP) of the implant survival and success rates was calculated for both groups and the pooled mean MBL was calculated for NDIs only. Heterogeneity was analysed using the Higgins (I^2) index. If I^2 was lower than or equal to 50%, a fixed-effects meta-analysis with inverse variance weighting was applied, and if it was greater than 50%, a random-effects meta-analysis

was performed according to the DerSimonian Laird method. In addition, differences in survival rate for the effect of implant position (anterior/posterior, maxilla/mandible) were analysed by calculating risk ratios (RRs) in a two-way meta-analysis using the inverse variance method for analysis of the overall effects. All statistical analyses were performed using Open Meta-Analyst version 10 (Brown University, Providence, RI, USA) (for the one-way meta-analysis) and Review Manager (version 5.4, The Nordic Cochrane Centre, The Cochrane Collaboration, Copenhagen, Denmark) (for the two-way meta-analysis).

Results

Study selection

The article selection process, summarised in the PRISMA flow diagram (Fig 1), resulted in 13,586 items which, after title screening, were reduced to 1793 abstracts. Following evaluation of the abstracts, 1501 were excluded, leaving 292 articles. The full texts were read and only 24[5,9,25-46] were useful for data extraction as they fulfilled the inclusion criteria. The kappa statistic for interrater agreement was 0.82 and thus deemed excellent.

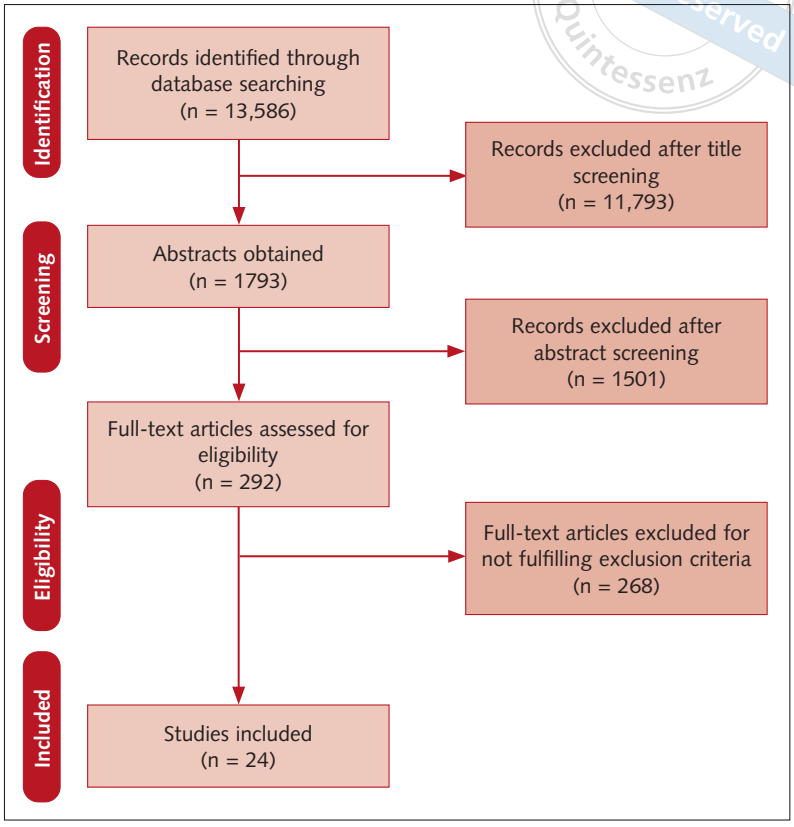

Fig 1 PRISMA flow diagram of the study selection process.

The only studies that explicitly compared the use of NDIs to SDIs in laterally regenerated bone were two consecutive studies by the same group of authors[47,48] that included only two NDIs within a larger group of implants with various diameters placed in non-regenerated bone but, given the small number of implants, these studies were eliminated.

Among the studies initially included in the SDI and horizontal augmentation group, three included NDIs placed in horizontally regenerated bone[25,27,28]. These three studies were included in this review and only data regarding SDIs in horizontally regenerated bone were extracted. Moreover, one study in the SDI and horizontal augmentation group enrolled clinical cases with bone defects after immediate implant placement[49]. This type of bone defect could not be considered as 'horizontal' and the data were not clearly reported; thus, this study was excluded because it produced mixed data[49]. Two studies were excluded because, after NDIs placed in regenerated bone were eliminated, the number of patients was less than 10[50,51]. One study was eliminated because it included NDIs placed in regenerated bone and the data resulting from them were not distinguishable from those for NDIs placed in native bone[523]. Only one study in the NDI group did not examine partially edentulous patients; in this study, however, the outcome data did not distinguish between the two types of patients[35]. The majority of the studies in the SDI and horizontal augmentation group involved partially edentulous patients, two did not specify the degree of edentulism[31,32] and one, despite stating that both partially and completely edentulous patients were included, did not present this distinction in the outcomes[29].

The basic characteristics of the studies, implants, interventions and outcomes are

Table 1 Characteristics of the included studies

Group	Study	Study design	Number of patients	Dropouts, n (%)	Age, y	Sex (M/F)	
SDIs and horizontal augmentation	Fugazzotto[25]	Retrospective	331	0 (0.0)	Mean 49.5, range 17–82	146/185	
	Chiapasco et al[26]	Prospective	30	0 (0.0)	Mean 41.2, range 19–60	12/18	
	Sethi and Kaus[27]	Prospective	150	24 (16.0)	Mean NR, range NR	72/78	
	Corinaldesi et al[28]	Retrospective	24	0 (0.0)	Mean 48.4, range 27–62	9/15	
	Boronat et al[29]	Retrospective	37	0 (0.0)	Mean 48.9, range 25–68	15/22	
	Urban et al[30]	Case series	22	0 (0.0)	Mean 49.9, range 30–63	5/17	
	Meijndert et al[31]	Prospective (RCT)	93	21 (22.6)	Mean 33.3, range 18–63	44/49	
	Merli et al[32]	Prospective (RCT)	50	0 (0.0)	Mean 54.7, range 30–76	17/33	
NDIs	Polizzi et al[33]	Prospective	21	0 (0.0)	Mean 30.0, range 13–58	8/13	
	Vigolo and Givani[34]	Retrospective	44	0 (0.0)	Mean 35.0, range 18–75	18/26	
	Hallman[35]	Prospective	40	1 (2.5)	Mean 57.0, range 20–86	15/25	
	Andersen et al[36]	Prospective	28	3 (10.7)	Mean 23.2, range 17–54	13/15	
	Froum et al[37]	Retrospective	27	0 (0.0)	Mean NR, range NR	NR	
	Sohn et al[38]	Retrospective	36	0 (0.0)	Mean 53.0, range 42–72	20/16	
	Tolentino et al[39]	Prospective (RCT)	42	0 (0.0)	Mean 57.2, range NR	NR	
	Maiorana et al[5]	Prospective	69	1 (1.4)	Mean 32.0, range NR	36/33	
	El-Sheikh and Shihabuddin[40]	Prospective	20	0 (0.0)	Mean 41.7, range 28–54	13/7	
	Pieri et al[42]	Prospective	50	0 (0.0)	Mean 41.6, range 18–65	18/32	
	King et al[43]	Prospective	38	0 (0.0)	Mean 24.0, range NR	18/20	
	Pieri et al[41]	Retrospective	49	5 (10.2)	Mean 61.0, range NR	11/38	
	Galindo-Moreno et al[45]	Prospective	69	5 (7.3)	Mean 32.5, range 18–72	36/33	
	Grandi et al[44]	Prospective	42	0 (0.0)	Mean 61.3, range 49–73	18/24	
	de Souza et al[9]	Prospective (RCT)	22	2 (0.4)	Mean 59.2, range NR	10/12	
	Si et al[46]	Retrospective	156	0 (0.0)	Mean 51.5, range 21–82	56/100	

NR, not reported; RCT, randomised controlled trial.

Table 2a Details of implants, materials and restorations in the SDI and horizontal augmentation group

Study	Implant diameter (mm)	Lateral augmentation technique	Biomaterial used	Membrane used	
Fugazzotto[25]	4.00	GBR	DFDAB, TCP	ePTFE	
Chiapasco et al[26]	3.75; 4.10	GBR vs block	Autogenous	ePFTE	
Sethi and Kaus[27]	3.75; 4.50; 5.50	Split crest	Hydroxyapatite and autogenous	None	
Corinaldesi et al[28]	3.75; 5.00	GBR	Autogenous	Titanium mesh	
Boronat et al[29]	3.70; 4.20	Onlay	Autogenous and DBBM	Collagen	
Urban et al[30]	3.75; 4.00	GBR	Autogenous or autogenous and DBBM	PGA/TMC	
Meijndert et al[31]	4.10	Onlay, GBR	Autogenous or DBBM	Collagen	
Merli et al[32]	4.00; 4.10	GBR	DBBM; TCP	Collagen	

DBBM, demineralised bovine bone mineral; DFDAB, demineralised freeze-dried allogeneic bone; ePTFE, expanded polytetrafluoroethylene; FDP, fixed dental prosthesis; GBR, guided bone regeneration; NR, not reported; PGA, polyglycolic acid; SC, single crown; TCP, tricalcium phosphate; TMC, trimethylene carbonate.

	Setting	Number of implants	Antibiotics	Implant position			
				Anterior	Posterior	Maxilla	Mandible
	Private practice	594	Preoperative and postoperative	196	430	341	285
	University	74	Preoperative and postoperative	32	42	52	22
	Private practice	449	No	NR	NR	329	0
	University	56	Preoperative and postoperative	18	38	21	35
	University	73	Preoperative and postoperative	26	47	28	45
	Private practice	58	Preoperative and postoperative	0	58	47	11
	University	93	NR	93	0	93	0
	Private practice	61	Preoperative and postoperative	NR	NR	NR	NR
	Private practice	30	NR	30	0	20	10
	Private practice	52	NR	30	22	29	23
	Private practice	160	Preoperative and postoperative	NR	NR	NR	NR
	University	32	NR	32	0	32	0
	University	48	Preoperative and postoperative	NR	NR	NR	NR
	University, private practice	62	Preoperative	62	0	8	54
	University	42	Postoperative	0	42	19	23
	University	97	Preoperative and postoperative	97	0	NR	NR
	University	40	Postoperative	0	40	0	40
	University	50	Preoperative and postoperative	50	0	36	14
	University	62	Preoperative	62	0	55	7
	Private practice	113	NR	0	113	NR	NR
	University	97	Preoperative	97	0	NR	NR
	Private practice	124	Preoperative and postoperative	0	124	0	124
	University	22	Postoperative	0	22	9	13
	University	243	NR	0	243	80	163

	Restoration type	Mean initial bone width (mm)	MBL measurement	Implant neck position	Timing of bone grafting
	SC, FDP	NR	Radiographic	Subcrestal	NR
	SC	< 4.00	Radiographic	NR	Before
	SC, FDP	2.00–4.00	Radiographic	Bone level	Simultaneous
	SC, FDP	NR	Radiographic	Bone level	13 simultaneous, 11 before
	NR	3.15	Radiographic	NR	Simultaneous
	SC, FDP	2.20	NR	NR	Before
	SC	NR	Radiographic	NR	Before
	SC	NR	Radiographic	NR	Simultaneous

Table 2b Details of implants and restorations in the NDI group

Study	Implant diameter (mm)	Restoration type	Mean initial bone width (mm)	MBL measurement	Implant neck position
Polizzi et al[33]	3.00	SC	NR	Radiographic	NR
Vigolo and Givani[34]	2.90	SC	NR	Radiographic	NR
Hallman[35]	3.30	SC, FDP	4.00	Radiographic	NR
Andersen et al[36]	3.25	SC	< 5.00	Radiographic	NR
Froum et al[37]	1.80; 2.20; 2.40	SC	NR	Radiographic	NR
Sohn et al[38]	3.00	SC, FDP	NR	Radiographic	Above the crest (one piece)
Tolentino et al[39]	3.30	SC	NR	NR	NR
Maiorana et al[5]	3.00	SC	NR	Radiographic	NR
El-Sheikh and Shihabuddin[40]	3.30	FDP	NR	Radiographic	NR
Pieri et al[42]	3.00	SC	5.00–6.00	Radiographic	Bone level
King et al[43]	3.00	SC	NR	Radiographic	NR
Pieri et al[41]	3.30	FDP	NR	NR	NR
Galindo-Moreno et al[45]	3.00	SC	NR	Radiographic	NR
Grandi et al[44]	2.75; 3.25	FDP	NR	Radiographic	Bone level
de Souza et al[9]	3.30	SC	NR	Radiographic	Above the crest (tissue level)
Si et al[46]	3.30	SC, FDP, cantilever	NR	Radiographic	54 tissue level, 189 bone level

FDP, fixed dental prosthesis; NR, not reported; SC, single crown.

presented in Tables 1, 2a and b and 3. In the absence of studies comparing the outcomes of NDIs vs SDIs placed in horizontally regenerated bone, a comparative meta-analysis could not be conducted. In the 24 studies included, a total of 1405 patients (738 NDI group, 667 SDI group) were analysed with a total of 2634 implants (1274 NDIs, 1360 SDIs).

Survival rate

A cumulative implant survival rate of 97.80% (1246/1274; PP 0.984, 95% confidence interval [CI] 0.977–0.991) over a mean follow-up period of 3.5 years was reported in the cumulative meta-analysis for the NDI protocol and no heterogeneity was detected among the included studies ($I^2 = 0.00\%$) (Fig 2). Similar results were obtained for the cumulative meta-analysis performed on studies evaluating the horizontal augmentation protocols, which showed a cumulative implant survival rate of 97.94% (1332/1360; PP 0.983, 95% CI 0.976–0.990) over a mean follow-up period of 3.22 years. In addition, no heterogeneity was detected for this group ($I^2 = 0.00\%$) (Fig 3).

The survival rate based on the prosthetic rehabilitation was not evaluated for the horizontal augmentation group due to the scarcity of available data. A cumulative survival rate of 98.19% (272/277; PP 0.981, 95% CI 0.965–0.997) was reported in the cumulative meta-analysis for NDIs rehabilitated with fixed dental prostheses (FDPs) and no heterogeneity was detected among the included studies ($I^2 = 0.00\%$) (Appendix 1, available at http://ijoi.quintessenz.de). A cumulative survival rate of 96.67% (493/510; PP 0.975, 95% CI 0.961–0.988) was reported in the cumulative meta-analysis for the NDIs rehabilitated with single crown (SC) prostheses, and no heterogeneity was detected among the included studies ($I^2 = 0.00\%$) (Appendix 2, available at http://ijoi.quintessenz.de).

No differences were detected for the NDIs in native bone and SDI and horizontal augmentation groups regarding survival rate related to mandibular/maxillary insertion ($P = 0.41$ and $P = 1.00$, respectively) and no heterogeneity was found for either group ($I^2 = 0.00\%$) (Appendices 3 and 4, available at http://ijoi.quintessenz.de). No difference was detected for the SDI and horizontal augmentation group regarding survival rate related to anterior/posterior location ($P = 0.55$) with a

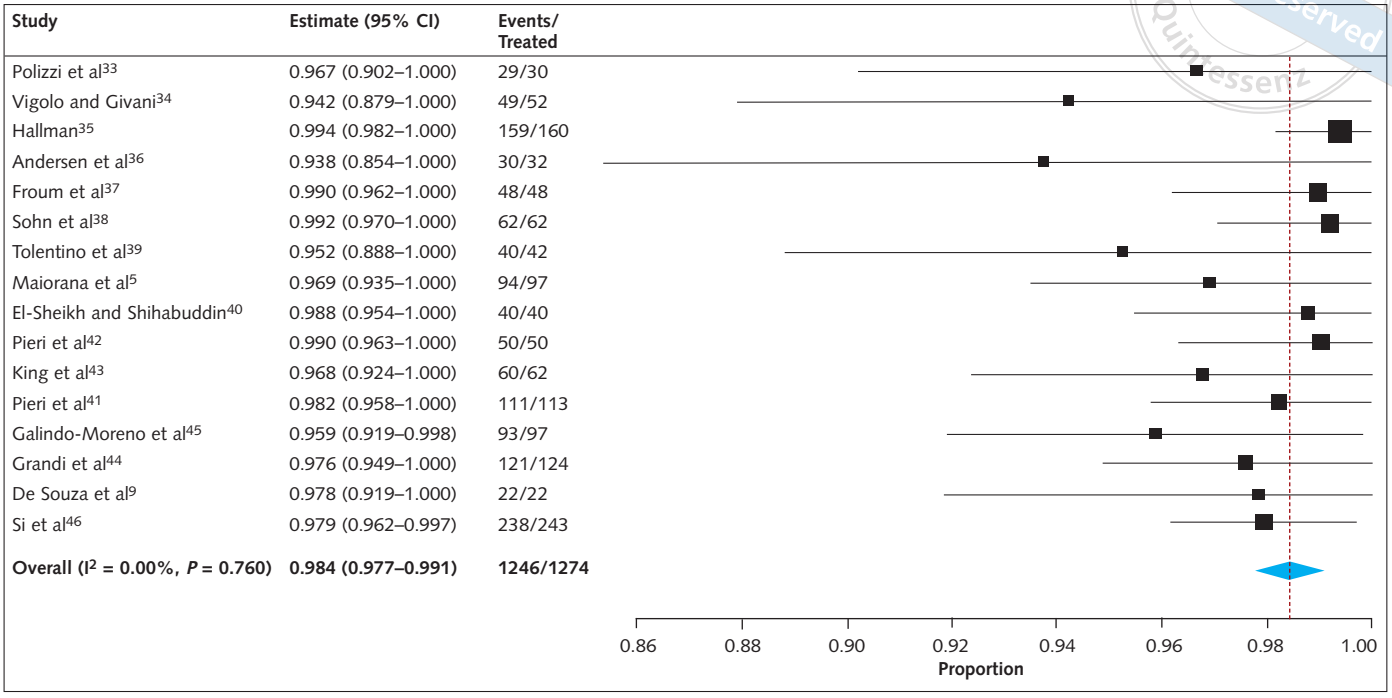

Fig 2 Cumulative survival rate for the NDI group.

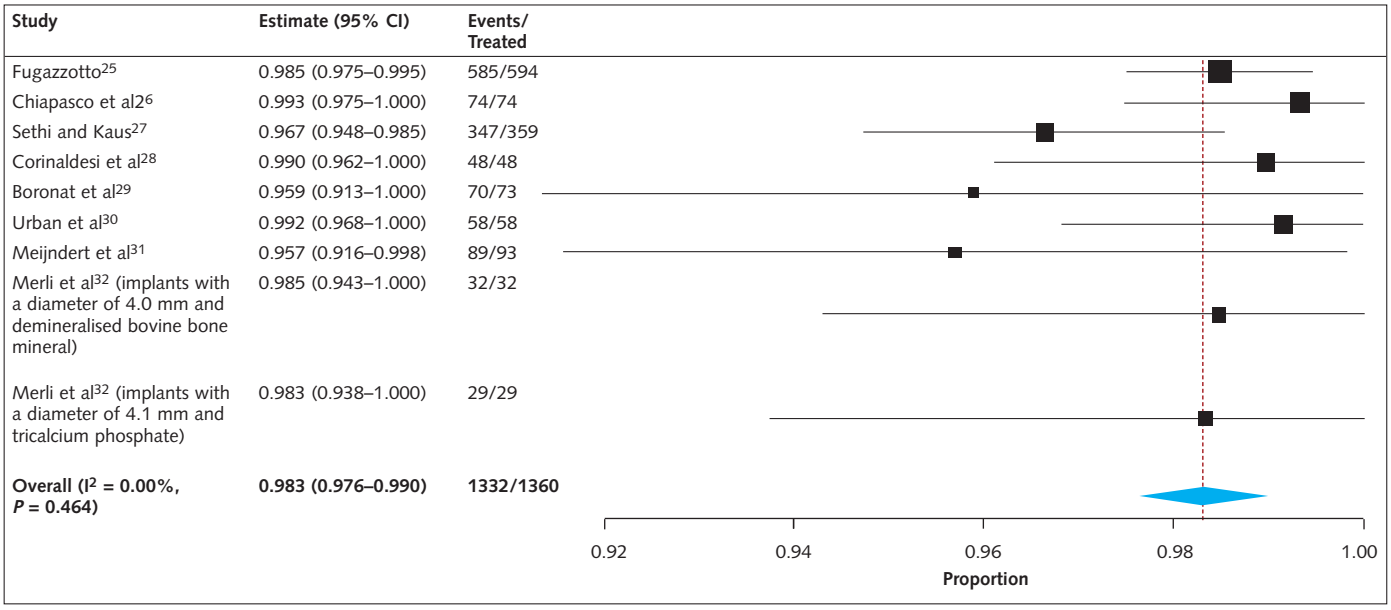

Fig 3 Cumulative survival rate for the SDI and horizontal augmentation group.

heterogeneity of 59% ($I^2 = 59.00\%$) (Appendix 5, available at http://ijoi.quintessenz.de). No analysis could be performed for the NDI group concerning anterior/posterior position due to a scarcity of data; in fact, in all studies except one, NDIs were placed either anteriorly only or posteriorly only.

Success rate

A cumulative implant success rate of 97.26% (604/621; PP 0.980, 95% CI 0.969–0.991) over a mean follow-up period of 3.70 years was reported in the meta-analysis for NDIs and no heterogeneity was detected among the included studies

Table 3 Reported outcomes

Group	Study	Follow-up (y)	Implant survival rate (implant level) (%)	Implant success rate (implant level) (%)	Implant dropouts	Implants lost (failed)	Location of implants lost (failed)			
							Anterior	Posterior	Maxilla	Mandible
SDIs and horizontal augmentation	Fugazzotto[25]	Range NR, mean 4.25	97.6	97.6	0	9	NR	NR	4	5
	Chiapasco et al[26]	Range 1.5–3.0, mean 1.9	100.0	95.8	0	0	0	0	0	0
	Sethi and Kaus[27]	Range 0.00–7.75, mean 2.25	97.0	NR	78	12	11	1	12	0
	Corinaldesi et al[28]	Range 3.00–8.00, mean 5.16	100.0	96.4	0	0	0	0	0	0
	Boronat et al[29]	Range 0–1, mean 1	95.9	95.9	0	3	3	0	NR	NR
	Urban et al[30]	Range NR, mean 3.8	100.0	NR	0	0	0	0	0	0
	Meijndert et al[31]	Range 0–10, mean 10	95.7	NR	21	4	4	0	4	0
	Merli et al[32]	Range NR, mean 1	100.0	100.0	0	0	NR	NR	NR	NR
NDIs	Polizzi et al[33]	Range 3.00–7.40, mean 5.25	96.7	NR	0	1	0	0	0	0
	Vigolo and Givani[34]	Range NR, mean 5	94.2	94.2	0	3	1	2	2	1
	Hallman[35]	Range NR, mean 1	98.8	96.3	0	1	NR	NR	NR	NR
	Andersen et al[36]	Range NR, mean 3	93.8	93.8	3	2	NR	NR	NR	NR
	Froum et al[37]	Range 1– 5, mean NR	100.0	NR	0	0	0	0	0	0
	Sohn et al[38]	Range 1.00–2.75, mean 1.90	100.0	100.0	0	0	0	0	0	0
	Tolentino et al[39]	Range 0.12–1.00, mean NR	95.2	NR	0	2	NR	NR	NR	NR
	Maiorana et al[5]	Range NR, mean 3	95.9	NR	0	4	4	0	NR	NR
	El-Sheikh and Shihabuddin[40]	Range NR, mean 1	100.0	NR	0	0	NA	0	NA	0
	Pieri et al[42]	Range NR, mean 3	100.0	100.0	0	0	0	NA	0	0
	King et al[43]	Range 0–3, mean NR	96.8	NR	0	2	2	0	NR	NR
	Pieri et al[41]	Range NR, mean NR	98.2	NR	NR	2	0	2	0	0
	Galindo-Moreno et al[45]	Range NR, mean 5	95.9	NR	NR	3	3	0	NR	NR
	Grandi et al[44]	Range NR, mean 1	97.6	NR	0	3 (ø2.75 2, ø3.25 1)	0	3 (ø2.75 2, ø3.25 1)	0	3 (ø2.75 2, ø3.25 1)
	de Souza et al[9]	Range NR, mean 3	100.0	95.0	2	0	0	0	0	0
	Si et al[46]	Range 1.40–12.00, mean 4.75	97.9	97.9	NR	5	NR	5	3	2

NA, not applicable; NR, not reported; RCT, randomised controlled trial.

	Mean bone gain (mm)	Biological complications					Prosthetic complications				MBL at 1 y, mean ± standard deviation	MBL at final evaluation, mean ± standard deviation (mm)
		Infections	Dehiscences	Suppuration	Peri-implantitis	Bone graft failure	Fracture	Chipping	Screw fracture	Loosening (decementation)		
	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR (NR)	NR	NR
	Group 1 2.70 ± 1.22, Group 2 4.00 ± 0.82	NR	NR	NR	NR	0	NR	NR	NR	NR (NR)	NR	NR
	NR	8	NR	NR	NR	7	NR	NR	NR	NR (NR)	NR	NR
	NR	NR	NR	NR	NR	0	NR	NR	NR	NR (NR)	NR	1.58 ± 0.48
	NR	2	8	NR	NR	2	NR	NR	NR	NR (NR)	NR	0.43 mesial, 0.49 distal, 0.64 overall
	5.56 ± 1.45	NR	NR	NR	NR	0	NR	NR	NR	NR (NR)	NR	NR
	NR	NR	NR	NR	NR	NR	0	9	0	0 (0)	NR	0.48 ± 1.19 mesial, 0.30 ±1.24 distal
	Ø4.0 DBBM 3.1 ± 1.2, Ø4.1 TCP 3.5 ± 1.7	3 (Ø4.0 DBBM 1, Ø4.1 TCP 2)	2	3	NR	NR	NR	NR	NR	NR (NR)	NR; Ø4.0 DBBM NR, Ø4.1 TCP NR	Ø4.0 DBBM 0.77 ± 0.36, Ø4.1 TCP 0.54 ± 0.45
	NA	0	0	0	0	NA	1	0	0	NR (NR)	NR	NR
	NA	NR	NR	NR	NR	NA	0	5	0	1 (7)	NR	0.8
	NA	1	NR	NR	4	NA	NR	NR	NR	NR (NR)	NR	NR
	NA	6	NR	NR	NR	NA	NR	2	NR	4 (2)	1.03 ± 0.41	0.52 ± 0.01
	NA	NR	NR	NR	NR	NA	NR	NR	0	2 (0)	NR	NR
	NA	NR	NR	NR	NR	NA	NR	NR	NR	NR (NR)	0.53 ± 0.37	NR
	NA	NR	NR	NR	NR	NA	0	NR	NR	NR (NR)	NR	NR
	NA	1	NR	NR	NR	NA	3	NR	NR	NR (NR)	0.11	0.34
	NA	NR	NR	NR	0	NA	0	0	0	1 (0)	0.19 ± 0.30	0.49 ± 0.60
	NA	0	NR	NR	NR	NA	0	1	0	1 (1)	0.21 ± 0.14	0.22 ± 0.14
	NA	1	NR	NR	NR	NA	5	NR	NR	1 (8)	NR	NR
	NA	2	NR	NR	3	NA	1	1	3	3 (4)	NR	NR
	NA	1	NR	NR	0	NA	7	NR	0	10 (0)	0.11 ± 1.02	NR
	NA	3 (ø2.75 2, ø3.25 1)	NR	3	NR	NA	0	0	0	0 (0)	0.47 (ø2.75 0.47, ø3.25 0.47)	NR; 3 (ø2.75 0.47, ø3.25 0.48)
	NA	0	0	0	0	NA	0	0	0	1 (8)	0.58 ± 0.39	0.58 ± 0.39
	NA	2	NR	NR	7	NA	2	19	0	7 (8)	NR	NR

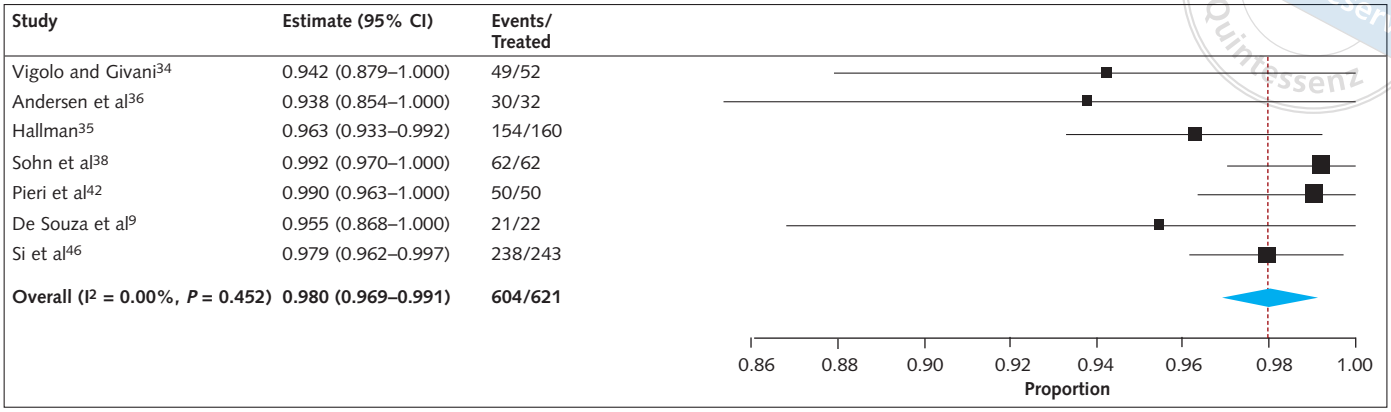

Fig 4 Cumulative success rate for the NDI group.

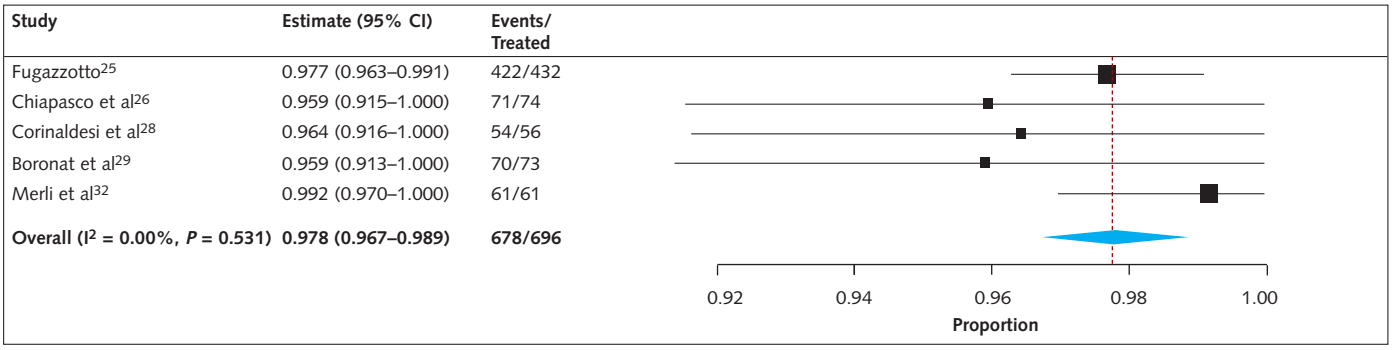

Fig 5 Cumulative success rate for the SDI and horizontal augmentation group.

(I^2 = 0.00%) (Fig 4). The results for the cumulative meta-analysis of the studies with horizontal augmentation protocols showed a cumulative implant survival rate of 97.41% (678/696; PP 0.978, 95% CI 0.967–0.989) over a mean follow-up period of 2.88 years, and no heterogeneity was detected (I^2 = 0.00%) (Fig 5).

MBL

MBL was not evaluated for the horizontal augmentation group due to the scarcity of available data. For the NDI group, MBL was analysed at 1 year (the time point at which data were available for most studies) and at the final time point, but only where the standard deviation was available. Cumulative MBL of 0.440 mm (95% CI 0.212–0.669) over a mean follow-up period of 2.90 years was reported at 1 year for NDIs and a heterogeneity of 97.00% was detected among the included studies (Appendix 6, available at http://ijoi.quintessenz.de). Cumulative MBL of 0.406 mm (95% CI 0.164–0.647) over a mean follow-up period of 3.20 years was reported at the final time point for NDIs and a heterogeneity of 99.12% was detected among the included studies; however, in this case only three studies could be included in the analysis for this time point (Appendix 7, available at http://ijoi.quintessenz.de).

Biological complications

A total of 13 infections occurred in the SDI group, reported in only three out of eight studies with an overall mean follow-up of 2.00 years. Eight of these infections were all related to a single study[27] which, however, included the second highest number of implants (449) in the SDI group; in the same group, a total of 10 wound dehiscences were reported in only two studies (eight and two dehiscences, respectively) with an overall mean follow-up of 1.00 year[29,32] and three cases

of suppuration were reported in only one study with a mean follow-up of 1.00 year[32]. No studies in the SDI group reported on peri-implantitis. Nine graft failures occurred in the SDI group with seven observed in only one study[27], the one that reported the highest number of infections.

Seventeen infections were reported in the NDI group, with the studies reporting them having an overall mean follow-up of 3.60 years[5,35,36,41,43,44,45,46], and only three cases of suppuration were noted, all in a single study with 124 implants[44]; the overall mean follow-up when including studies that clearly reported zero cases of suppuration was 2.55 years, and although the infections were distributed across several studies, one in particular reported six of them[41], whereas five studies out of 16 reported none[34,37-40]. No wound dehiscences were noted in the only study out of 16 that reported about them[9]. Fourteen cases of peri-implantitis were recorded in the SDI group, with the studies that reported them having an overall mean follow-up of 4.03 years. Seven were recorded in one study only with the highest number of implants (243) in the NDI group[46], but nine studies did not report this outcome. Due to the aforementioned scarcity and variability in reporting data on biological complications, their analysis is restricted to being descriptive rather than statistical.

Prosthetic complications

Only one study in the SDI group reported about prosthetic complications, with nine cases of chipping and no fractures recorded[31].

Nineteen cases of fracture were reported in six out of 16 studies in the NDI group[5,33,41,43,45,46], whereas four studies did not mention this outcome[35-38]. Within the fracture cases, only one involved the implant neck[33]; in all other cases the abutment was involved. Twenty-eight cases of chipping were reported in five studies[34,36,41,42,46], with 19 being from a single study[47] whereas seven studies[5,35,37-39,43,45] did not report this outcome. Only three cases of screw fracture were reported, all in one study[41]. A total of 31 cases of loosening and 38 of decementation were reported; five studies did not report this outcome[5,33,35,38,39]. As with biological complications, data were scarce and reported by too few studies with only a descriptive analysis provided. The overall mean follow-up for the studies that reported prosthetic complications was 3.70 years.

Quality assessment

The results of the risk of bias assessment for the included cohort studies, case series and randomised controlled trials (RCTs) following the recommendations of the Joanna Briggs Institute are reported in Appendix 8a-d (available at http://ijoi.quintessenz.de). Overall, eight studies[5,33,36,38,41,43,45,53] out of 24 were considered as having a moderate risk of bias, and four[9,25,34,37] exhibited a high risk of bias.

Discussion

The present systematic review, despite the lack of comparative meta-analysis, presents interesting data about the use of NDIs and SDIs placed in horizontally regenerated bone. Many studies on the use of NDIs, several of which are well designed, are already present in the literature and show high survival rates, but there are many considerations to be made.

The survival rate for NDIs (97.80%) was similar to that for SDIs placed in regenerated bone (97.94%), and the range was also similar for the two groups (95.70%–100.00% for SDIs and 93.75%–100.00% for NDIs).

The sub-analysis of implant location (maxilla/mandible and anterior/posterior) reported no differences between the two groups. This sub-analysis was particularly important because there was great variability regarding implant position within the different studies, particularly in the SDI and horizontal augmentation group; however, in some studies patients were treated only in the anterior or posterior region, or only in the maxilla, thus restricting the analysis to four studies (three for anterior/posterior) that had more complete data in the SDI and horizontal augmentation group and five in the NDI group but only for maxillary/mandibular location.

Bone augmentation, whether contextual or prior to implant placement, undoubtedly adds another operatory variable that, besides having a considerable short-term influence (increased morbidity, longer surgical time, increased risk of infection), may also have a long-term influence depending on the stability of the regenerated bone over time.

Besides the good results for survival rate, there are also critical biomechanical and aesthetic aspects to consider regarding NDIs. From a biomechanical perspective, it is known that diameters smaller than 3.75 mm can be more subject to fracture of the implant–prosthesis interface components[54,55]. This has been tested in vitro, showing that implants with a narrower diameter have a higher fracture rate when subjected to load resistance tests, both in tensile strength tests and in the maximum bending moment[56]. Nevertheless, mechanical test analyses have shown that the overload on NDIs is considerably reduced when they are splinted together when compared to non-splinted NDIs and even non-splinted SDIs; however, NDIs do not seem suitable for 'all-on-four' rehabilitations due to the increased load stress during occlusal function[57]. The data from the present systematic review could to some extent confirm this last observation. Indeed, the studies with the highest survival rates were those including only FDPs or FDPs with SCs, namely splinted NDIs[35,37,38,40,41,44]. A recent study published after the search process for the present systematic review found that the rate of mechanical complications was higher for NDIs positioned in the posterior rather than anterior region[58] and, although this is certainly due to the higher concentration of functional loads in this region, most of the mechanical complications reported were ceramic chipping and crown loosening.

From an aesthetic point of view, a problem is posed by the creation of an emergence profile that, starting with a small diameter and having to widen abruptly in the transition zone, would create a very convex profile that in some cases might not provide adequate support to the soft tissues[59]. This effect, most significant in the aesthetic zones, would certainly be more pronounced for teeth with a greater crown width, and mitigated by placing the implant neck more apically in the bone; however, this would create a longer transmucosal path. The consequences of an emergence profile with an overly accentuated angle not only have a negative impact on the aesthetic profile but are also significantly more likely to result in peri-implantitis, as Katafuchi et al[60] showed for implants with emergence angles greater than 30 degrees. On the other hand, if wishing to solve the problem of an overly convex emergence profile by deepening the implant placement and thus creating a longer transmucosal path, an increased vertical cantilever would be obtained that would result in an increased risk of fracture[61].

As no RCTs in the literature compared NDIs with SDIs in horizontally regenerated bone, an analysis of several non-randomised and non-comparative studies was conducted, thus a comparative meta-analysis was not possible. Including non-randomised and non-comparative studies, however, can be extremely useful when RCTs are not available, because this makes it possible to include a larger body of literature in the search strategy and studies without control groups can always provide information on long-term efficacy, rare events and adverse effects[62]. These kinds of studies can be included if they have a strong and transparent design; as such, a thorough quality appraisal like the one carried out in the present review should be performed[62].

While only two studies reported on NDIs in comparison with SDIs placed in regenerated bone[47,48], as already explained in the results, the NDIs in these studies represented only two implants in a larger group of implants with various diameters. Thus, the specific aim of the present study was not to compare NDIs to SDIs, but rather implants placed in native bone to those placed in regenerated bone.

Although an RCT was recently published comparing NDIs to SDIs placed in horizontally regenerated bone, the follow-up period was only 4 months and NDIs, unlike SDIs, were loaded immediately[63]; for these reasons, it could not be included in the present review.

The limitations of the present systematic review are the data available in the literature; although

numerous studies report on the two types of treatment, few compare them directly. In fact, since there are no RCTs available that compare NDIs inserted in native bone with SDIs placed in regenerated bone, the present authors turned their efforts towards providing a separate analysis and systematic review of the two methods in order to present at least those data relating to survival and success that can be compared even if not directly. A less specific analysis of the comparison between SDIs and NDIs, regardless of bone regeneration, would certainly have yielded more results, and probably also studies directly comparing the two types of therapy, but the present authors did not aim to analyse SDIs placed in non-augmented bone, but rather to assess the specificity of NDIs as a therapeutic alternative to performing horizontal regeneration. This implies a further limitation: although NDIs are not a simple alternative to SDIs, they often represent an alternative to other types of rehabilitation than horizontal regeneration, such as the placement of implants in areas with insufficient mesiodistal space. The present authors believe, however, that this topic, one that is equally specific as that examined in the present study, should be the subject of a separate systematic review in order not to generate confusion. The lack of a uniform definition of a 'narrow implant' certainly represents another limitation of this review.

Conclusion

The present systematic review recorded high and comparable survival rates between NDIs and SDIs placed in regenerated bone. Despite not having found RCTs in the literature and therefore not being able to provide a comparative meta-analysis, the present authors believe that this systematic review offers interesting cues and, above all, important initial data that can be used to guide the realisation of RCTs that compare NDIs placed in native bone to SDIs placed in horizontally regenerated bone. Well-designed RCTs, following the criteria suggested in this review, will certainly be able to confirm, correct or refute the results provided by the non-comparative studies analysed here.

References

1. Esposito M, Grusovin MG, Felice P, Karatzopoulos G, Worthington HV, Coulthard P. Interventions for replacing missing teeth: Horizontal and vertical bone augmentation techniques for dental implant treatment. Cochrane Database Syst Rev 2009;2009:CD003607.
2. Degidi M, Piattelli A, Carinci F. Clinical outcome of narrow diameter implants: A retrospective study of 510 implants. J Periodontol 2008;79:49–54.
3. Maló P, de Araújo Nobre M. Implants (3.3 mm diameter) for the rehabilitation of edentulous posterior regions: A retrospective clinical study with up to 11 years of follow-up. Clin Implant Dent Relat Res 2011;13:95–103.
4. Akça K, Çehreli MC, Iplikçioğlu H. Evaluation of the mechanical characteristics of the implant-abutment complex of a reduced-diameter morse-taper implant: A nonlinear finite element stress analysis. Clin Oral Implants Res 2003;14:444–454.
5. Maiorana C, King P, Quaas S, Sondell K, Worsaae N, Galindo-Moreno P. Clinical and radiographic evaluation of early loaded narrow-diameter implants: 3 years follow-up. Clin Oral Implants Res 2015;26:77–82.
6. Schiegnitz E, Al-Nawas B. Narrow-diameter implants: A systematic review and meta-analysis. Clin Oral Implants Res 2018;29(suppl 16):21–40.
7. Lee JS, Kim HM, Kim CS, Choi SH, Chai JK, Jung UW. Long-term retrospective study of narrow implants for fixed dental prostheses. Clin Oral Implants Res 2013;24:847–852.
8. Ioannidis A, Gallucci GO, Jung RE, Borzangy S, Hämmerle CHF, Benic GI. Titanium-zirconium narrow-diameter versus titanium regular-diameter implants for anterior and premolar single crowns: 3-year results of a randomized controlled clinical study. J Clin Periodontol 2015;42:1060–1070.
9. de Souza AB, Sukekava F, Tolentino L, César-Neto JB, Garcez-Filho J, Araújo MG. Narrow- and regular-diameter implants in the posterior region of the jaws to support single crowns: A 3-year split-mouth randomized clinical trial. Clin Oral Implants Res 2018;29:100–107.
10. Elnayef B, Porta C, Suárez-López Del Amo F, Mordini L, Gargallo-Albiol J, Hernández-Alfaro F. The fate of lateral ridge augmentation: A systematic review and meta-analysis. Int J Oral Maxillofac Implants 2018;33:622–635.
11. Aghaloo TL, Moy PK. Which hard tissue augmentation techniques are the most successful in furnishing bony support for implant placement? Int J Oral Maxillofac Implants 2007;(22, suppl):49–70.
12. Mijiritsky E, Mazor Z, Lorean A, Levin L. Implant diameter and length influence on survival: Interim results during the first 2 years of function of implants by a single manufacturer. Implant Dent 2013;22:394–398.
13. Jackson BJ. Small diameter implants: Specific indications and considerations for the posterior mandible: A case report. J Oral Implantol 2011;37:156–164.
14. Jokstad A, Brägger U, Brunski JB, Carr AB, Naert I, Wennerberg A. Quality of dental implants. Int Dent J 2003;53(6, suppl 2):409–443.
15. Christensen GJ. Observations: The increased use of small-diameter implants. J Am Dent Assoc 2009;140:709–712.
16. Flanagan D. Fixed partial dentures and crowns supported by very small diameter dental implants in compromised sites. Implant Dent 2008;17:182–191.
17. Bidra AS, Almas K. Mini implants for definitive prosthodontic treatment: A systematic review. J Prosthet Dent 2013;109:156–164.

18. Mundt T, Schwahn C, Stark T, Biffar R. Clinical response of edentulous people treated with mini dental implants in nine dental practices. Gerodontology 2015;32:179–187.
19. Al-Johany SS, al Amri MD, Alsaeed S, Alalola B. Dental implant length and diameter: A proposed classification scheme. J Prosthodont 2017;26:252–260.
20. Moher D, Hopewell S, Schulz KF, et al. CONSORT 2010 explanation and elaboration: Updated guidelines for reporting parallel group randomised trials. BMJ 2010;340:c869.
21. Moola S, Munn Z, Aromataris E, et al. Chapter 7: Systematic reviews of etiology and risk. In: Aromataris E, Munn Z (eds). Joanna Briggs Institute Manual for Evidence Synthesis. The Joanna Briggs Institute, 2020.
22. Misch CE, Perel ML, Wang HL, et al. Implant success, survival, and failure: The International Congress of Oral Implantologists (ICOI) Pisa Consensus Conference. Implant Dent 2008;17:5–15.
23. Albrektsson T, Zarb G, Worthington P, Eriksson AR. The long-term efficacy of currently used dental implants: A review and proposed criteria of success. Int J Oral Maxillofac Implants 1986;1:11–25.
24. Valente NA, Andreana S. Peri-implant disease: What we know and what we need to know. J Periodontal Implant Sci 2016;46:136–151.
25. Fugazzotto PA. Success and failure rates of osseointegrated implants in function in regenerated bone for 6 to 51 months: A preliminary report. Int J Oral Maxillofac Implants 1997;12:17–24.
26. Chiapasco M, Abati S, Romeo E, Vogel G. Clinical outcome of autogenous bone blocks or guided bone regeneration with e-PTFE membranes for the reconstruction of edentulous ridges. Clin Oral Implants Res 1999;10:278–288.
27. Sethi A, Kaus T. Maxillary ridge expansion with simultaneous implant placement: 5-year results of an ongoing clinical study. Int J Oral Maxillofac Implants 2000;15:491–499.
28. Corinaldesi G, Pieri F, Sapigni L, Marchetti C. Evaluation of survival and success rates of dental implants placed at the time of or after alveolar ridge augmentation with an autogenous mandibular bone graft and titanium mesh: A 3- to 8-year retrospective study. Int J Oral Maxillofac Implants 2009;24:1119–1128.
29. Boronat A, Carrillo C, Peñarrocha M, Peñarrocha M. Dental implants placed simultaneously with bone grafts in horizontal defects: A clinical retrospective study with 37 patients. Int J Oral Maxillofac Implants 2010;25:189–196.
30. Urban IA, Nagursky H, Lozada JL. Horizontal ridge augmentation with a resorbable membrane and particulated autogenous bone with or without anorganic bovine bone-derived mineral: A prospective case series in 22 patients. Int J Oral Maxillofac Implants 2011;26:404–414.
31. Meijndert CM, Raghoebar GM, Meijndert L, Stellingsma K, Vissink A, Meijer HJA. Single implants in the aesthetic region preceded by local ridge augmentation; a 10-year randomized controlled trial. Clin Oral Implants Res 2017;28:388–395.
32. Merli M, Moscatelli M, Mariotti G, Pagliaro U, Raffaelli E, Nieri M. Comparing membranes and bone substitutes in a one-stage procedure for horizontal bone augmentation. Three-year post-loading results of a double-blind randomised controlled trial. Eur J Oral Implantol 2018;11:441–452.
33. Polizzi G, Fabbro S, Furri M, Herrmann I, Squarzoni S. Clinical application of narrow Brånemark system implants for single-tooth restorations. Int J Oral Maxillofac Implants 1999;14:496–503.
34. Vigolo P, Givani A. Clinical evaluation of single-tooth mini-implant restorations: A five-year retrospective study. J Prosthet Dent 2000;84:50–54.
35. Hallman M. A prospective study of treatment of severely resorbed maxillae with narrow nonsubmerged implants: Results after 1 year of loading. Int J Oral Maxillofac Implants 2001;16:731–736.
36. Andersen E, Saxegaard E, Knutsen BM, Haanaes HR. A prospective clinical study evaluating the safety and effectiveness of narrow-diameter threaded implants in the anterior region of the maxilla. Int J Oral Maxillofac Implants 2001;16:217–224.
37. Froum SJ, Cho SC, Cho YS, Elian N, Tarnow D. Narrow-diameter implants: A restorative option for limited interdental space. Int J Periodontics Restorative Dent 2007;27:449–455.
38. Sohn DS, Bae MS, Heo JU, Park JS, Yea SH, Romanos GE. Retrospective multicenter analysis of immediate provisionalization using one-piece narrow-diameter (3.0-mm) implants. Int J Oral Maxillofac Implants 2011;26:163–168.
39. Tolentino L, Sukekava F, Seabra M, Lima LA, Garcez-Filho J, Araújo MG. Success and survival rates of narrow diameter implants made of titanium-zirconium alloy in the posterior region of the jaws – Results from a 1-year follow-up. Clin Oral Implants Res 2014;25:137–141.
40. El-Sheikh AM, Shihabuddin OF. Clinical and radiographic evaluation of narrow-diameter titanium-zirconium implants in unilateral atrophic mandibular distal extensions: A 1-year pilot study. J Contemp Dent Pract 2015;15:417–422.
41. Pieri F, Forlivesi C, Caselli E, Corinaldesi G. Narrow- (3.0 mm) versus standard-diameter (4.0 and 4.5 mm) implants for splinted partial fixed restoration of posterior mandibular and maxillary jaws: A 5-year retrospective cohort study. J Periodontol 2017;88:338–347.
42. Pieri F, Siroli L, Forlivesi C, Corinaldesi G. Clinical, esthetic, and radiographic evaluation of small-diameter (3.0-mm) implants supporting single crowns in the anterior region: A 3-year prospective study. Int J Periodontics Restorative Dent 2014;34:825–832.
43. King P, Maiorana C, Luthardt R, et al. Clinical and radiographic evaluation of a small-diameter dental implant used for the restoration of patients with permanent tooth agenesis (hypodontia) in the maxillary lateral incisor and mandibular incisor regions: A 36-month follow-up. Int J Prosthodont 2016;29:147–153.
44. Grandi T, Svezia L, Grandi G. Narrow implants (2.75 and 3.25 mm diameter) supporting a fixed splinted prostheses in posterior regions of mandible: One-year results from a prospective cohort study. Int J Implant Dent 2017;3:1–7.
45. Galindo-Moreno P, Nilsson P, King P, et al. Clinical and radiographic evaluation of early loaded narrow-diameter implants: 5-year follow-up of a multicenter prospective clinical study. Clin Oral Implants Res 2017;28:1584–1591.
46. Si M, Zhang Y, Li J, He F. Retrospective study on the clinical outcomes of small-diameter implants supporting fixed prostheses without bone augmentation in the posterior region after 2 to 12 years. Clin Implant Dent Relat Res 2019;21:454–461.
47. Widmark G, Andersson B, Andrup B, Carlsson GE, Ivanoff CJ, Lindvall AM. Rehabilitation of patients with severely resorbed maxillae by means of implants with or without bone grafts. A 1-year follow-up study. Int J Oral Maxillofac Implants 1998;13:474–482.
48. Widmark G, Andersson B, Carlsson GE, Lindvall AM, Ivanoff CJ. Rehabilitation of patients with severely resorbed maxillae by means of implants with or without bone grafts: A 3- to 5-year follow-up clinical report. Int J Oral Maxillofac Implants 2001;16:73–79.
49. Corrente G, Abundo R, Cardaropoli D, Cardaropoli G, Martuscelli G. Long-term evaluation of osseointegrated implants in regenerated and nonregenerated bone. Int J Periodontics Restorative Dent 2000;20:390–397.

50. De Boever AL, De Boever JA. Guided bone regeneration around non-submerged implants in narrow alveolar ridges: A prospective long-term clinical study. Clin Oral Implants Res 2005;16:549–556.
51. Yamauchi K, Takahashi T, Nogami S, Kataoka Y, Miyamoto I, Funaki K. Horizontal alveolar distraction osteogenesis for dental implant: Long-term results. Clin Oral Implants Res 2013;24:563–568.
52. Jensen OT, Cullum DR, Baer D. Marginal bone stability using 3 different flap approaches for alveolar split expansion for dental implants–A 1-year clinical study. J Oral Maxillofac Surg 2009;67:1921–1930.
53. Di Stefano D, Gastaldi G, Vinci R, Cinci L, Pieri L, Gherlone E. Histomorphometric comparison of enzyme-deantigenic equine bone and anorganic bovine bone in sinus augmentation: A randomized clinical trial with 3-year follow-up. Int J Oral Maxillofac Implants 2015;30:1161–1167.
54. Davarpanah M, Martinez H, Tecucianu JF, Celletti R, Lazzara R. Small-diameter implants: Indications and contraindications. J Esthet Dent 2000;12:186–194.
55. Gross MD. Occlusion in implant dentistry. A review of the literature of prosthetic determinants and current concepts. Aust Dent J 2008;53(suppl 1):S60–S68.
56. Neto HT, Tuzita AS, Gehrke SA, de Vasconcellos Moura R, Casati MZ, Mesquita AMM. A comparative analysis of implants presenting different diameters: Extra-narrow, narrow and conventional. Materials (Basel) 2020;13:1888.
57. Valera-Jiménez JF, Burgueño-Barris G, Gómez-González S, López-López J, Valmaseda-Castellón E, Fernández-Aguado E. Finite element analysis of narrow dental implants. Dent Mater 2020;36:927–935.
58. Alrabiah M, Al Deeb M, Alsahhaf A, et al. Clinical and radiographic assessment of narrow-diameter and regular-diameter implants in the anterior and posterior jaw: 2 to 6 years of follow-up. J Periodontal Implant Sci 2020;50:97–105.
59. Steigmann M, Monje A, Chan HL, Wang HL. Emergence profile design based on implant position in the esthetic zone. Int J Periodontics Restorative Dent 2014;34:559–563.
60. Katafuchi M, Weinstein BF, Leroux BG, Chen YW, Daubert DM. Restoration contour is a risk indicator for peri-implantitis: A cross-sectional radiographic analysis. J Clin Periodontol 2018;45:225–232.
61. Sayyedi A, Rashidpour M, Fayyaz A, et al. Comparison of stress distribution in alveolar bone with different implant diameters and vertical cantilever length via the finite element method. J Long Term Eff Med Implants 2019;29:37–43.
62. Fitzpatrick-Lewis D, Ciliska D, Thomas H. The Methods for the Synthesis of Studies without Control Groups. Hamilton: National Collaborating Centre for Methods and Tools, 2009.
63. Barausse C, Esposito M, Pistilli R, Buti J, Felice P. Immediate loading of 3 mm-diameter implants as an alternative to horizontal bone augmentation for placing normal diameter implants: 4-month post-loading results from a multicentre randomized controlled trial. Clinical Trials in Dentistry 2019;1:51–66.

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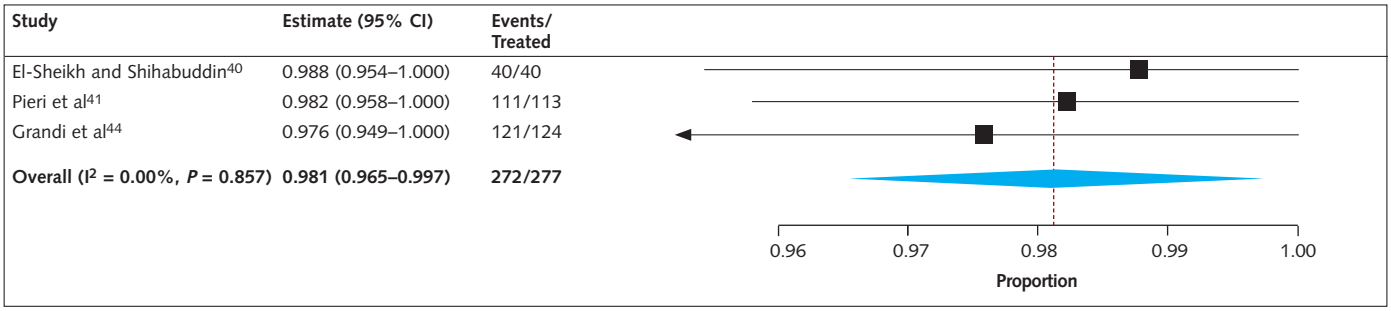
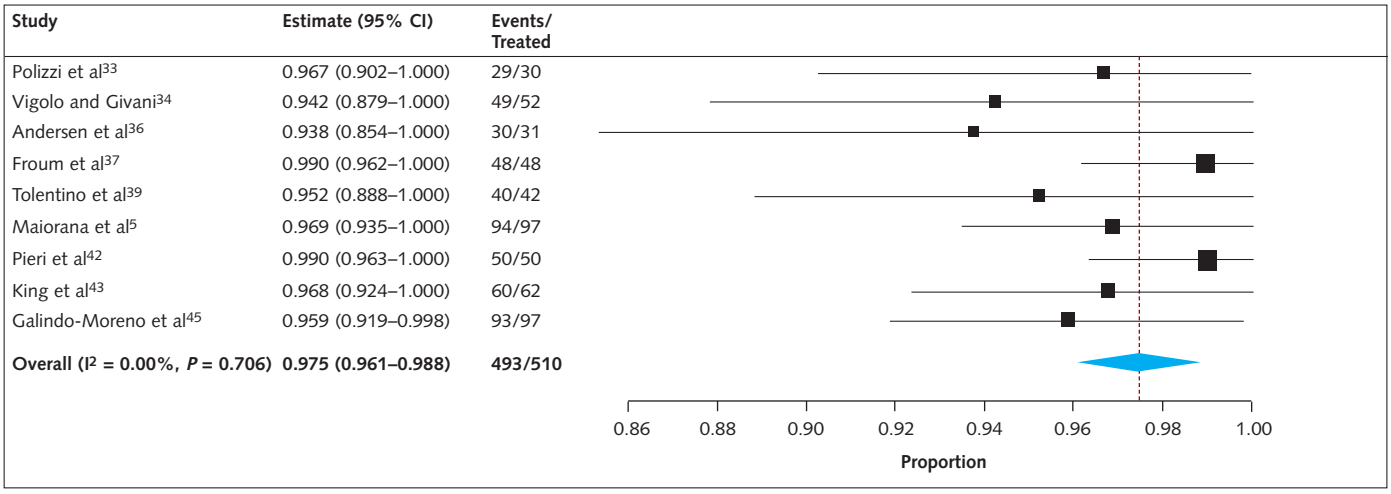
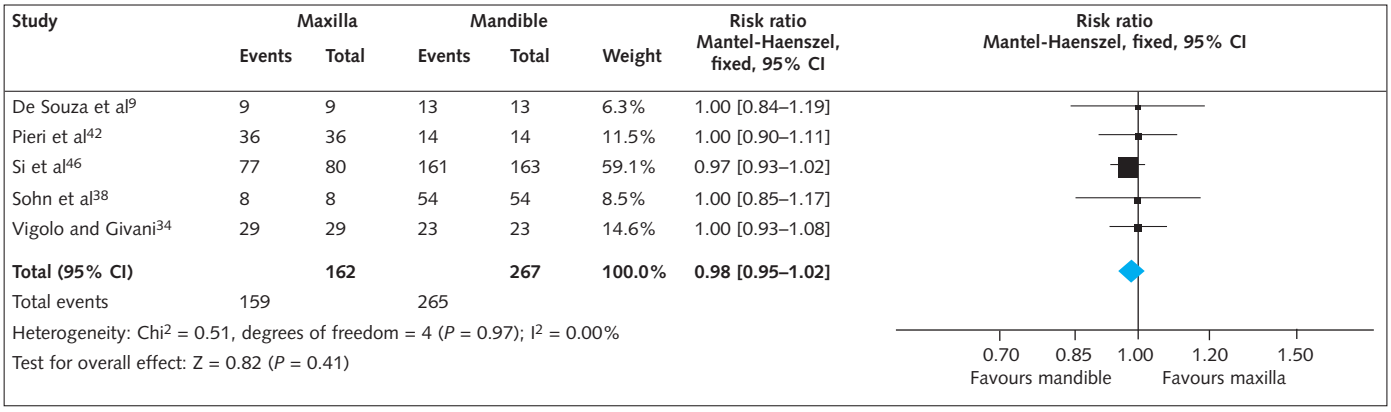
Appendix



Appendix 1 Cumulative survival rate of NDIs rehabilitated with FDPs.



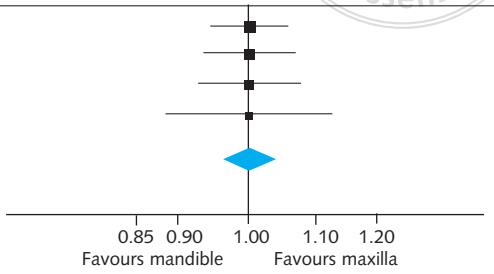
Appendix 2 Cumulative survival rate of NDIs rehabilitated with SCs.



Appendix 3 Comparison of the survival rate of NDIs placed in the mandible or maxilla.

Study	Maxilla		Mandible			Risk ratio Mantel-Haenszel, fixed, 95% CI
	Events	Total	Events	Total	Weight	
Boronat et al[29]	28	28	45	45	31.4%	1.00 [0.94–1.06]
Chiapasco et al[26]	52	52	22	22	28.0%	1.00 [0.94–1.07]
Corinaldesi et al[28]	21	21	35	35	24.1%	1.00 [0.93–1.08]
Urban et al[30]	47	47	11	11	16.4%	1.00 [0.89–1.13]
Total (95% CI)		**148**		**113**	**100.0%**	**1.00 [0.96–1.04]**
Total events	159		265			

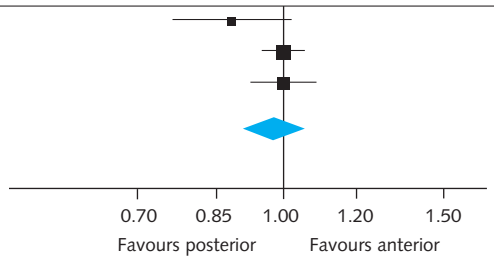
Heterogeneity: Chi² = 0.00, degrees of freedom = 3 (P = 1.00); I² = 0.00%
Test for overall effect: Z = 0.00 (P = 1.00)



Appendix 4 Comparison of the survival rate of SDIs placed in the mandible or maxilla.

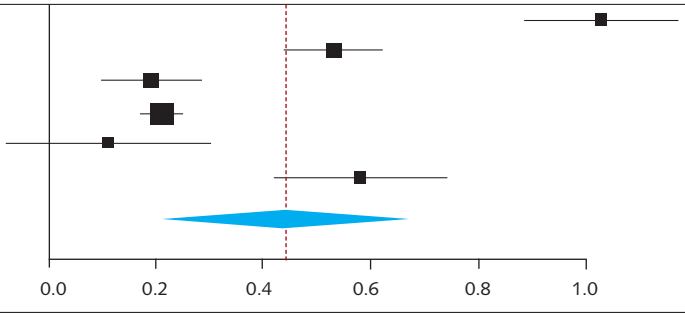
Study	Anterior		Posterior			Risk ratio Mantel-Haenszel, fixed, 95% CI
	Events	Total	Events	Total	Weight	
Boronat et al[29]	23	26	47	47	18.9%	0.88 [0.76–1.02]
Chiapasco et al[26]	32	32	42	42	45.7%	1.00 [0.95–1.05]
Corinaldesi et al[28]	18	18	38	38	35.5%	1.00 [0.92–1.09]
Total (95% CI)		**76**		**127**	**100.0%**	**0.98 [0.90–1.06]**
Total events	73		127			

Heterogeneity: Tau² = 0.00; Chi² = 4.92, degrees of freedom = 2 (P = 0.09); I² = 59.00%
Test for overall effect: Z = 0.60 (P = 0.55)



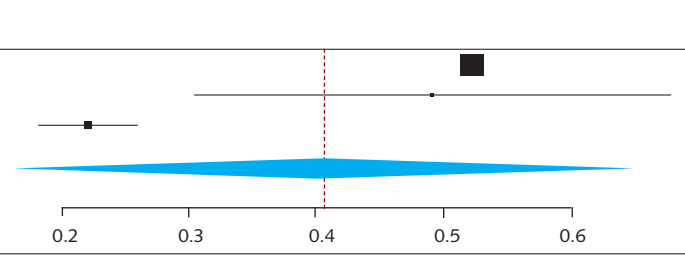
Appendix 5 Comparison of survival rate of SDIs placed in the posterior or anterior region.

Study	Estimate (95% CI)
Andersen et al[36]	1.030 (0.888–1.172)
Sohn et al[38]	0.530 (0.438–0.622)
El-Sheikh and Shihabuddin[40]	0.190 (0.097–0.283)
Pieri et al[42]	0.210 (0.171–0.249)
Galindo-Moreno et al[45]	0.110 (–0.081–0.301)
De Souza et al[9]	0.580 (0.417–0.743)
Overall (I² = 97.00%, P < 0.001)	**0.440 (0.212–0.669)**



Appendix 6 Cumulative MBL for the NDI group at the 1-year follow-up.

Study	Estimate (95% CI)
Andersen et al[36]	0.520 (0.517–0.523)
El-Sheikh and Shihabuddin[40]	0.490 (0.304–0.676)
Pieri et al[42]	0.220 (0.181–0.259)
Overall (I² = 99.12%, P < 0.001)	**0.406 (0.164–0.647)**



Appendix 7 Cumulative MBL for the NDI group at the final follow-up.

Appendix 8a Assessment of quality and risk of bias for the cohort studies reporting on NDIs or SDIs placed in horizontally regenerated bone. Each domain was satisfied (yes), not satisfied (no), unclear or not assessable (N/A) according to the Joanna Briggs Institute Critical Appraisal tool

Study	Were the two groups similar and recruited from the same population?	Were the exposures measured similarly to assign people to both exposed and unexposed groups?	Was the exposure measured in a valid and reliable way?	Were confounding factors identified?	Were strategies to deal with confounding factors stated?	
Fugazzotto[25]	N/A	N/A	Yes	No	No	
Polizzi et al[33]	N/A	N/A	Yes	No	No	
Sethi and Kaus[27]	N/A	N/A	Yes	No	No	
Vigolo and Givani[34]	N/A	N/A	No	No	No	
Hallman[35]	N/A	N/A	N/A	No	No	
Andersen et al[36]	Yes	N/A	N/A	No	No	
Froum et al[37]	N/A	N/A	No	No	No	
Corinaldesi et al[28]	Yes	Yes	Yes	Unclear	Unclear	
Boronat et al[29]	N/A	N/A	Yes	Yes	Yes	
Sohn et al[38]	N/A	N/A	Yes	No	No	
Pieri et al[42]	N/A	N/A	N/A	No	No	
El-Sheikh and Shihabuddin[40]	N/A	N/A	Yes	No	No	
Maiorana et al[5]	N/A	N/A	Yes	No	No	
Pieri et al[41]	Yes	N/A	N/A	No	No	
King et al[43]	Yes	N/A	N/A	No	No	
Galindo-Moreno et al[45]	N/A	N/A	No	N/A	N/A	
Grandi et al[44]	N/A	N/A	Yes	N/A	N/A	
Si et al[46]	N/A	N/A	No	Unclear	Unclear	

Appendix 8b Assessment of quality and risk of bias for case series reporting on NDIs or SDIs placed in horizontally regenerated bone. Each domain was satisfied (yes), not satisfied (no) or not assessable (N/A) according to the Joanna Briggs Institute Critical Appraisal tool

Study	Were there clear criteria for inclusion?	Was the condition measured in a standard, reliable way?	Were valid methods used for identification of the condition?	Did the case series have consecutive inclusion of participants?	Did the case series have complete inclusion of participants?	
Urban et al[30]	Yes	Yes	Yes	Yes	Yes	

Appendix 8c Assessment of quality and risk of bias for quasi-experimental studies reporting on NDIs or SDIs placed in horizontally regenerated bone. Each domain was satisfied (yes), not satisfied (no) or not assessable (N/A) according to the Joanna Briggs Institute Critical Appraisal tool

Study	Is it clear in the study what is the 'cause' and what is the effect?	Were the participants included in any comparisons similar?	Were the participants included in any comparisons receiving similar treatment/care, other than the exposure or intervention of interest?	Was there a control group?	Were there multiple measurements of the outcome both pre- and post-intervention/ exposure?	
Chiapasco et al[26]	Yes	Yes	Yes	Yes	Yes	

	Were the groups/ participants free of the outcome at the start of the study (or at the moment of exposure)?	Were the outcomes measured in a valid and reliable way?	Was the follow-up time reported and sufficient to be long enough for outcomes to occur?	Was follow-up complete, and if not, were the reasons to loss to follow-up described and explored?	Were strategies to address incomplete follow-up utilised?	Was appropriate statistical analysis used?	Overall risk of bias
	Yes	Yes	Yes	Yes	No	No	High
	Yes	Yes	Yes	Yes	N/A	Yes	Moderate
	Yes	Yes	Yes	Yes	N/A	Yes	Low
	Yes	No	Yes	Yes	No	Unclear	High
	Yes	Yes	Yes	Yes	Yes	Yes	Low
	Yes	Yes	Yes	Yes	N/A	Unclear	Moderate
	Yes	No	Yes	Yes	N/A	No	High
	Yes	Yes	Yes	Yes	Yes	Yes	Low
	Yes	Yes	Yes	Yes	N/A	No	Low
	Yes	Yes	Yes	Yes	N/A	Unclear	Moderate
	Yes	Yes	Yes	N/A	N/A	Yes	Moderate
	Yes	Yes	Yes	Yes	N/A	Yes	Low
	Yes	Yes	Yes	Yes	Unclear	Yes	Moderate
	Yes	Yes	Yes	Yes	N/A	Yes	Moderate
	Yes	Yes	Yes	Yes	N/A	Yes	Moderate
	Yes	No	Yes	Yes	Yes	Yes	Moderate
	Yes	Yes	Yes	Yes	N/A	Yes	Low
	Yes	Yes	Yes	Yes	Yes	Yes	Low

	Was there clear reporting of the participant demographics?	Was there clear reporting of clinical information?	Were the outcomes or follow-up results clearly reported?	Was there clear reporting of the site demographic?	Was the statistical analysis appropriate?	Overall risk of bias
	Yes	Yes	Yes	Yes	Yes	Low

	Was follow-up complete and if not, were differences between groups in terms of their follow-up adequately described and analysed?	Were the outcomes of participants included in any comparisons measured in the same way?	Were outcomes measured in a reliable way?	Was appropriate statistical analysis used?	Overall risk of bias
	Yes	Yes	Yes	No	Low

Appendix 8d Assessment of quality and risk of bias for randomised controlled trials reporting on NDIs or SDIs placed in horizontally regenerated bone. Each domain was satisfied (yes), not satisfied (no) or not assessable (N/A) according to the Joanna Briggs Institute Critical Appraisal tool

Study	Was true randomisation used?	Was allocation concealed?	Were groups similar at baseline?	Were participants blind to treatment assignment?	Were those delivering treatment blind to treatment assignment?	Were outcome assessors blind to treatment assignment?	Were treatment groups treated identically other than the intervention of interest?	
Tolentino et al[39]	Yes	Unclear	Yes	Unclear	Unclear	Yes	Yes	
Merli et al[32]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	
Meijndert et al[31]	Unclear	Unclear	Yes	No	N/A	Unclear	Yes	
de Souza et al[9]	No	No	Unclear	No	No	No	Yes	

	Was follow-up complete or differences in terms of follow-up adequately described and analysed?	Were participants analysed in the groups to which they were randomised?	Were outcomes measured in the same way for treatment groups?	Were outcomes measured in a reliable way?	Was appropriate statistical analysis used?	Was the trial design appropriate?	Overall risk of bias
	Yes	Yes	Yes	No	Yes	Yes	Low
	Yes	Yes	Yes	Yes	Yes	Yes	Low
	Yes	N/A	Yes	Yes	Yes	Unclear	Low
	Yes	N/A	Yes	Yes	Yes	No	High