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Clinical, radiographic, and aesthetic outcomes at two narrow-diameter implants to replace congenital missing maxillary lateral incisors: A 3-year prospective, clinical study

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Abstract

Introduction: To present the 3-year clinical, radiographic, and aesthetic outcomes in patients with congenitally missing lateral incisors rehabilitated with two narrow-diameter implants (NDIs).

Methods: The original population consisted of 100 patients rehabilitated with a cement-retained bi-layered zirconia single-unit crown supported by either a Ø2.9 mm (Test) or a Ø3.3 mm (Control) NDI ($n = 50$). At the 1- and 3-year follow-up (T2, T3), implant survival rate, crestal bone level (CBL) changes, biological, and technical complications were recorded, while the assessment of the aesthetic outcomes was performed using the Copenhagen Index Score.

Results: Seventy-four patients Ø2.9 mm ($n = 39$) or Ø3.3 mm ($n = 35$) reached T3, as 24 patients were lost to follow-up and 1 implant (Ø3.3 mm) was removed. Throughout the observation period, minimal CBL changes (i.e., <1 mm) were detected between groups. Despite the positive aesthetic scores recorded (i.e., 1–2), at T3 20% of patients rehabilitated with a Ø3.3 mm versus 2.6% of patients Ø2.9 mm displayed an alveolar process deficiency (Score 3). No additional technical and/or mechanical complications were recorded between T2 and T3. Tooth vitality was maintained in all neighboring teeth. Peri-implant probing depths and plaque scores remained low in both groups ($p > 0.05$).

Conclusion: The use of 2.9 or 3.3 diameter implants showed comparable favorable mid-term results in terms of survival rate, CBL, and aesthetic outcomes. Hence, clinicians should rely on the use of such NDIs when replacing maxillary lateral incisors.

KEYWORDS
clinical research, clinical trials, dental implants, patient centered outcomes, prosthodontics

Summary Box

What is known?

Narrow diameter implants (NDIs) do represent a reliable treatment option to rehabilitate single-unit tooth gaps in case of limited bone volume. Nowadays, only short-term follow-up studies with contradictory results are available.

What this study adds?

This 3-year clinical, radiographic, and aesthetic evaluation shows the comparable favorable mid-term results between two NDIs. Hence, clinicians should rely on the use of such NDIs when replacing maxillary lateral incisors.

1 | INTRODUCTION

Tooth agenesis is a frequent dental anomaly, which, if left untreated, may cause severe aesthetic and functional impairments.[1,2] Its prevalence has been reported to be around 7% with the maxillary lateral incisor (MLI) being the second most frequently affected tooth group (24.3%).[1,2]

Treatment planning and oral rehabilitation of young patients with agenesis most often require an interdisciplinary approach including orthodontic treatment (space closure by canine substitution or space creation), oral surgery, and eventually fixed prosthetic rehabilitation (i.e., resin-bonded bridges or fixed dental prostheses).[3–7] Over the past three decades, implant-supported single-unit crowns have been increasingly used to replace congenital MLIs.[8–10] More recently, narrow-diameter implants (NDIs) have been introduced to overcome local anatomical challenges such as the limited mesiodistal space and root proximity of the adjacent teeth, and better achieve symmetry with contralateral peg-shaped MLIs, frequently observed in patients with unilateral MLI agenesis.[11]

Positive short-term results in terms of implant survival rate, peri-implant crestal bone level (CBL) changes, and clinical and aesthetic results have been documented in a large cohort of patients treated with two NDIs.[12] Very recently, the clinical safety and performance of 2.9 mm NDIs in different clinical scenarios (i.e., maxillary and mandibular incisors) was documented by Walter and co-workers in a multicenter study reporting a 92.7% of implant survival rate after 1 year of loading.[13] Focusing on mid-term outcomes (i.e., with a follow-up of 3 years), satisfactory results have been published in two prospective clinical studies on NDIs with 3.0 mm[14] and 3.3 mm,[15] respectively. However, due to the lack of a control group and the limited number of patients included, the overall validity of the data obtained could be questioned.

Therefore, given the limited evidence available, the aim of the present study was to document the development of clinical, radiographic, and aesthetic outcomes of bone-level tapered NDI with a diameter of 2.9 mm to replace congenitally missing MLIs compared with the same type of implant with a diameter of 3.3 mm in a large population from baseline to 3 years of follow-up.

2 | MATERIALS AND METHODS

This study was designed as a 5-year, prospective, non-randomized, controlled clinical trial with two parallel study groups conducted at the Department of Oral & Maxillofacial Surgery, Copenhagen University Hospital, Copenhagen, Denmark. Approval to store and handle the data was provided by the Danish Data Protection Agency (approval number: 2012-58-0004). The investigation was conducted in accordance with the revised principles of the 2013 Declaration of Helsinki. Informed consent was obtained from each patient before the start of the study.

This trial was not registered prior to enrollment of the first patient (i.e., 08.2016) since not required by the local national legislation.

Data reporting was performed according to the STROBE guidelines.

2.1 | Study design and population characteristics

Between 2016 and 2018, patients with uni- or bilateral MLIs (i.e., 12 and/or 22) who referred to the Department of Oral & Maxillofacial Surgery, Copenhagen University Hospital, Copenhagen, Denmark and who met the inclusion criteria received dental implants based on the mesiodistal distance (MD) between the canine and the central incisor measured with a caliper. Specifically, patients with an MD of 5.9 to 6.3 mm received a dental implant with a diameter of 2.9 mm [Ø2.9 mm] (Straumann BLT implant, Roxolid®, SLActive®, Straumann AG, Basel, Switzerland), while patients presenting with a MD of 6.4 mm to 7.1 mm received a dental implant with a diameter of 3.3 mm [Ø 3.3 mm] (Straumann BLT implant, Roxolid®, SLActive®).

2.2 | Surgical and prosthetic procedures

Details of the surgical[16] and prosthetic procedures performed have been previously reported in the 1-year report.[12] Briefly, following standard implant placement, peri-implant dehiscence and fenestration bone defects were augmented with simultaneous contour augmentation using guided bone regeneration (GBR) by means of locally

harvested autogenous bone chips applied on the exposed implant surface in combination with demineralized bovine bone mineral (DBBM; Bio-Oss® Geistlich Pharma AG, Wolhusen, Switzerland) and a double-layer collagen membrane (Bio-Gide®, Geistlich Pharma AG, Wolhusen, Switzerland).[17] If the facial bone wall thickness after implant osteotomy was <1.7 mm, GBR was performed using DBBM alone covered with a double-layer collagen membrane. During the healing phase, patients were rehabilitated with a flipper to allow proper oral hygiene procedures. Three months after implant placement, a provisional screw-retained polymethylmethacrylate single-unit crown was delivered. Following an additional period of 3 months, a feldspatic-ceramic-veneered-zirconia crown on a customized CAD/CAM titanium abutment was fabricated and cemented (Phosphate cement or Zinc-phosphate cement). This appointment was considered the baseline examination (T1).

2.3 | Supportive periodontal/peri-implant care program and follow-up examination

At the completion of the active treatment (T1), patients were referred to their private dental practitioners for individual maintenance programs. Patients were invited for a follow-up examination 1 year (T2) and 3 years (T3) after crown delivery.

2.4 | Clinical examinations

At the T2 and T3 follow-up, the clinical examination was performed by the same experienced dental hygienist (V.N.) under the supervision of the senior author (S.S.J.) and included implant survival rate, defined as the presence of the installed implant in the oral cavity and reconstruction survival defined as the presence of the implant-supported single-unit crown on the implant. In addition, at each implant site peri-implant probing depth(PPD) in mm at six sites per implant, presence of plaque, exudation or suppuration after probing (0/1), presence of fistula, pain and necrosis of the adjacent teeth were recorded. Finally, loosening or fracture of the abutment, loss of retention of the reconstruction (i.e., decementation of the reconstruction) and fracture or chipping of the veneering ceramic, were recorded.

2.5 | Radiographic and aesthetic assessment

Digital periapical non-standardized and nonindividualized intraoral radiographs were taken using the paralleling technique after implant placement (T0), and at T1, T2, and T3 follow-up examinations. Images were then imported into a dedicated software (Zen pro, Carl Zeiss AG, Oberkochen, Germany) and the known implant lengths (i.e., 10 or 12 mm) were used to calibrate the images. CBLs were assessed on the mesial and distal aspect of the implants as the linear distance between the implant shoulder and the first bone-to-implant contact. Therefore, all positive values indicated bone gain, while negative values defined bone loss. The aesthetic assessment was based on clinical photographs of the restorations[18] at T1, T2, and T3. To assess the aesthetic outcomes, the Copenhagen Index Score was used as previously described[19] and validated[20] scoring all the evaluated parameters from 1 (optimal) to 4 (not-sufficient).

All radiographic measurements and aesthetic assessments were undertaken independently and in duplicate by two periodontists (A.R.; J-C.I.) not involved in any part of the treatments or follow-up examinations.

2.6 | Statistical analysis

In cases with bilateral MLIs, where implants with identical diameters were placed, only one implant was randomly selected for the statistical analysis (www.randomization.com).

2.6.1 | Sample size calculation

Sample size calculation was performed on the secondary outcome parameter: peri-implant crestal bone resorption according to Hosseini et al. (2013).[21] More in detail, a mean crestal bone loss of 0.6 mm in the test group and 0.2 mm in the control group were considered significant. Therefore, in order to detect a difference of 0.4 mm and a standard deviation of 0.6, 49 patients per group were needed with an alpha (type I error) = 0.05 and a pf power = 0.9. Using an independent sample *t*-test a group size of $N = 49$ was calculated. Patients' number per group was rounded to 50.

2.7 | Data analysis

Each patient contributed with one dental implant only and was, therefore, considered as the statistical unit. Descriptive analysis was performed providing absolute and relative frequencies for categorical variables and mean, standard deviation, for continuous variables. Normal distribution of the quantitative measures was checked by Kolmogorov–Smirnov test. Two-sample *t*-test was used to compare mean CBL between both implant groups. The calculated interexaminer agreement with Dahlberg's d test was in the range 0.07–0.08 mm and the intraclass correlation coefficient was estimated at 0.987 providing a very high level of reproducibility of the performed measurements.

Chi^2 independence, Kendall's Tau-b, and Fisher's exact test were used to assess the association between categorical/ordinal aesthetic variables and group. Similar tests were used to compare collected parameters (i.e., width of the alveolar process, width of the alveolar ridge, thickness of the facial bone after osteotomy) and need of bone regeneration between groups. Mann–Whitney's test and Spearman's correlation were used to assess distributions between groups and relationship between clinical/intraoperative and aesthetic parameters respectively. All the tests were two-tailed, and the level of significance

TABLE 1 Patients (implants) characteristics within the two groups (2.9 diameter; 3.3 diameter) throughout the study period.

	2.9 Ø	3.3 Ø	*p*
Baseline (i.e., definitive crown delivery) (T1)	50	49	1.000
1-year (T2)	47	45	0.715
3-year (T3)	39	35	0.452
Implant loss	0	1	1.000
Dropouts	11	14	0.452

Note: Chi-square and Fisher's exact test were used for comparisons.

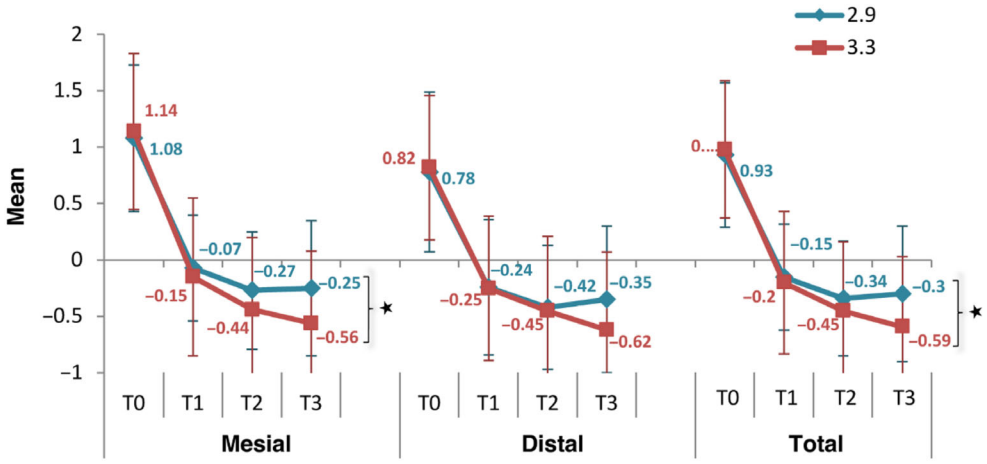

FIGURE 1 Mesial, distal, and total crestal bone level changes over time within the two groups. *Significant difference between groups $p < 0.05$.

was set at 5%. The statistical analysis was performed by a professional biostatistician with a commercially available dedicated software (SPSS 15.0, Chicago, IL, USA).

3 | RESULTS

3.1 | Population characteristics

The original population consisted of 100 patients rehabilitated with 100 dental implants Ø2.9 mm ($n = 50$) or Ø3.3 mm ($n = 50$). At T0, no statistically significant differences were found with respect to the variables patient's age, gender, and implant length ($p > 0.05$).[16] At the 3-year follow-up examination, a total of 25 patients (Ø2.9 mm [$n = 11$]; Ø3.3 mm [$n = 14$]) had dropped out. The reasons for drop-out were either unwillingness to attend the examination or that the patients had moved abroad.

Details of the patient characteristics and dropouts are listed in Table 1.

3.2 | Implant survival rate, CBL changes, peri-implant biological and technical complications

At the 3-year follow-up, no additional implants were lost after one implant loss prior to loading (i.e., one early implant failure) in the Ø3.3 mm group, leading to an implant survival rate of 100% in the Ø2.9 mm group and 98% in the Ø3.3 mm group without statistically significant difference between groups ($p = 1.000$; 95% CI: 94.6%–99.9%).

CBL changes over time differed statistically significant between the two groups at the three-time intervals (T3–T0; T3–T1, T3–T2): more specifically, during the 3 years of functional loading (T3–T1), a CBL change of −0.17 ± 0.30 mm in the Ø2.9 mm and −0.42 ± 0.4.2 mm Ø3.3 was detected ($p = 0.005$). Similar differences were detected between the latest follow-up and both the time of implant placement (T3–T0; $p = 0.025$) and the 1-year follow-up (T3–T2; $p = 0.014$). CBL changes over the 3-year period are illustrated in Figure 1.

At T3, mean PPD values were 2.62 ± 0.31 mm in the Ø2.9 mm group and 2.57 ± 0.38 mm in Ø3.3 mm group respectively, with no statistically significant difference between groups ($p = 0.482$).

Mean plaque scores did not statistically significant differ between the 2 groups neither at T2 nor at T3: 15% in the Ø2.9 mm group and 12% in the in Ø3.3 mm group ($p = 0.631$) (T2) and 15% in the Ø2.9 mm group and 10% in the in Ø3.3 mm group ($p = 0.369$) (T3). At T3, 2 patients (1 per group) presented a buccal fistula not associated with an increased PPD and/or interproximal radiographic signs of crestal bone loss. No radiographic or clinical signs of changes in the vitality of the adjacent teeth were noted. Finally, between T2 and T3 no additional technical complications were detected.

CBL changes at the different time points are illustrated in Figures 1 and 2.

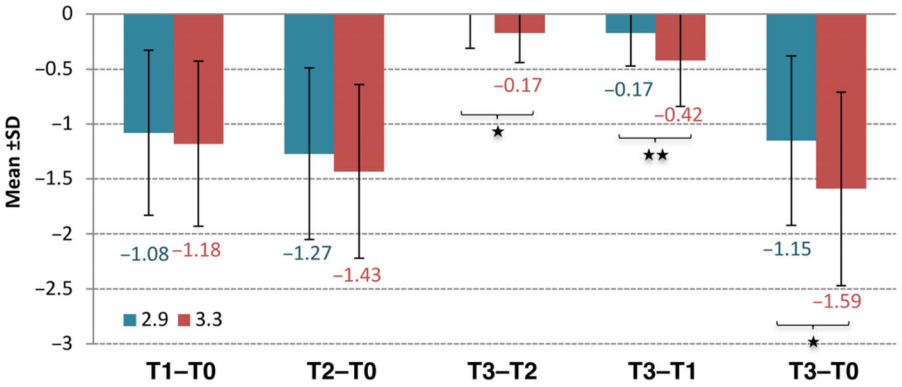

FIGURE 2 Differences in crestal bone loss between time points within and between the two groups. *Significant difference between groups $p < 0.05$, **significant difference between groups $p < 0.01$.

3.3 | Aesthetic parameters

Between T2 and T3, the peri-implant soft tissue color changed consistently (Score 3: presence of discoloration), reaching 15.4% in the Ø2.9 mm and 14.3% in the Ø3.3 mm group ($p = 0.135$). At T3, alveolar process deficiency Score 3 was detected at 2.6% of the Ø2.9 mm and 20% of the Ø3.3 mm implants. This difference was statistically significant different between T2 and T3 within the Ø3.3 mm group ($p = 0.029$) but not between the two groups ($p = 0.105$).

Complete papilla fill (Score 1) or papilla fill of at least half of the interproximal space (Score 2) was recorded at T3 in almost all cases, with no statistically significant difference between mesial ($p = 0.546$) and distal sites ($p = 0.477$). Finally, a similar trend was observed for all other investigated parameters, failing to reveal any statistically significant differences over time ($p > 0.05$).

Details of the aesthetic outcomes are provided in Tables 2 and 3.

4 | DISCUSSION

The aim of this study was to document the development of clinical, radiographic, and aesthetic outcomes of NDIs with a diameter of 2.9 or 3.3 mm for the replacement of MLIs from baseline to 3 years of loading.

Overall, the 3-year results are consistent with those published after 12 months of loading: more specifically, no additional implants were lost underlining the reliability of both implants for tooth replacement in single-unit gaps not also in the midterm. Our results are slightly better than those recently published by Walter et al.[13] who reported an implant survival rate of 92.7% at 1 year after placement of 41 2.9 mm diameter implants. Possible explanations could be found in the differences in inclusion and exclusion criteria, the use of such an implant in different clinical scenarios (i.e., maxillary and mandibular incisors) and the fact that all patients in the present study were young and healthy.

With respect to interproximal CBL changes over time, both groups demonstrated limited radiographic changes (i.e., <1 mm) at both 1- and 3-year follow-up (Figure 1). However, at the latest follow-up examination, a statistically significant difference (i.e., 0.3 vs. 0.59 mm) between the two groups was detected ($p < 0.05$). A similar trend has been detected with respect to peri-implant crestal bone loss, where minimal loss was assessed after the initial physiologic crestal remodeling between implant placement and prosthetic loading (T1–T0; T2–T0).[12] Consequently, it can be speculated that the increased osteotomy for the placement of a Ø3.3 mm, could also potentially compromise CBL over time.

Aesthetic outcome is one of the most important aspects of modern implant dentistry, especially for young patients with implants placed in the anterior maxilla.[22] When focusing on the results of the present cohort, it must be underlined that most of implant sites exhibiting good/optimal (i.e., Scores 1 and 2) results at T2, remained stable at T3. However, with respect to one of the most relevant aesthetic parameters (i.e., soft tissue color), it must be emphasized how a statistically significant worsening was detected between T2 and T3 in both groups (i.e., $p = 0.014$ and 0.005) with only 25.6% (Ø 2.9 mm) and 5.7% (Ø 3.3 mm) of the rehabilitated implants achieving Score 1, respectively. A possible explanation for this could be that peri-implant soft tissue augmentation procedures were never performed in the present study, based on the scientific assumption that a GBR procedure would be sufficient not only to achieve optimal peri-implant conditions but also to create an ideal long-term aesthetic outcome.[23]

Another finding is that the presence of 15% of patients at the latest follow-up exhibiting peri-implant soft tissue color mismatch (i.e., grayness or redness) might be interpreted as the consequence of thinning of the buccal bone wall and/or of peri-implant soft tissue, which might have a more detrimental consequence for the aesthetics when using Ti-abutments (Figure 5). Historically, to overcome such complication, the use of zirconia abutment has been proposed[24] with contradictory results in terms of peri-implant color match.[25] However, for the 2.9 mm diameter implants such an abutment solution was not available when this study was initiated and therefore a custom-made Ti-abutment was used in all patients.

An additional interesting finding is that 20% of patients rehabilitated with a 3.3 mm diameter implant had a score of 3 with respect to the presence of an alveolar process deficiency at T3, compared with only 2.6% of patients who received a 2.9 mm diameter implant (Figure 5). This result may provide indirect evidence that the application of a GBR procedure concomitant with implant placement, performed in 34 versus 22 cases in the 3.3 and 2.9 mm groups respectively, does not entirely prevent buccal bone wall resorption in

TABLE 2 Frequency of aesthetic scores within the Ø2.9 and Ø3.3 mm groups at baseline (T1) and 1-year (T2) and 3-year follow-up examination (T3).

		T1			T2			T3		
		Ø2.9 mm	Ø3.3 mm		Ø2.9 mm	Ø3.3 mm		Ø2.9 mm	Ø3.3 mm	
		$n = 47$	$n = 45$	*p*-value	$n = 47$	$n = 45$	*p*-value	$n = 39$	$n = 35$	*p*-value
Symmetry/harmony	1	39.1%	31.8%	0.769	39.1%	33.3%	0.698	38.5%	37.1%	0.595
	2	41.3%	63.6%		41.3%	61.9%		43.6%	57.1%	
	3	19.6%	4.5%		19.6%	4.8%		17.9%	5.7%	
Soft tissue color	1	47.8%	43.2%	0.978	39.1%	35.7%	0.747	25.6%	5.7%	0.135
	2	43.5%	56.8%		47.8%	61.9%		59.0%	80.0%	
	3	8.7%	0.0%		13.0%	2.4%		15.4%	14.3%	
Papilla index (mesial)	1	63.0%	55.8%	0.438	65.2%	73.2%	0.420	59.0%	54.3%	0.546
	2	37.0%	41.9%		34.8%	26.8%		41.0%	40.0%	
	3	0.0%	2.3%		0.0%	0.0%		0.0%	5.7%	
Papilla index (distal)	1	82.2%	97.6%	**0.013**	93.3%	100%	0.073	79.5%	85.7%	0.477
	2	17.8%	2.4%		6.7%	0.0%		20.5%	14.3%	
Level of the margin	1	69.6%	86.4%	**0.049**	69.6%	83.3%	0.112	64.1%	85.7%	**0.023**
	2	30.4%	13.6%		28.3%	16.7%		33.3%	14.3%	
	3	0.0%	0.0%		2.2%	0.0%		2.6%	0.0%	
Soft tissue texture	1	65.2%	84.1%	**0.035**	84.8%	92.9%	0.223	71.8%	54.3%	0.085
	2	34.8%	15.9%		15.2%	7.1%		28.2%	40.0%	
	3	0.0%	0.0%		0.0%	0.0%		0.0%	5.7%	
Soft tissue curvature	1	84.8%	95.5%	0.083	93.5%	95.2%	0.720	82.1%	88.6%	0.425
	2	15.2%	4.5%		6.5%	4.8%		17.9%	11.4%	
Alveolar process deficiency	1	71.7%	59.1%	0.182	58.7%	50.0%	0.240	51.3%	40.0%	0.105
	2	28.3%	38.6%		41.3%	40.5%		46.2%	40.0%	
	3	0.0%	2.3%		0.0%	9.5%		2.6%	20.0%	
Cement excess (0/1)	No	91.3%	95.5%	0.677	97.8%	97.6%	1.000	97.4%	97.1%	0.938
	Yes	8.7%	4.5%		2.2%	2.4%		2.6%	2.9%	

Note: Symmetry/harmony: assessment according to facial midline, tooth axis, contralateral tooth and smile line. Score 1: excellent; score 2: suboptimal but satisfactory; score 3: moderate; score 4: poor symmetry and harmony. Soft tissue score: Score 1: no discoloration, score 2: light grayish discoloration, score 3: distinguishable grayish discoloration, score 4: metal or abutment visible. Papilla index: Score 1: papilla filling the entire proximal space; score 2: papilla filling at least half of the entire proximal space; score 3: papilla filling less than half of the proximal space, score 4: no papilla. Level of the margin: assessment of the apically or incisally position of the buccal marginal peri-implant mucosa in the middle of the implant crown compared with the contralateral tooth or the neighboring teeth. Score 1: match; score 2: slight mismatch; score 3: moderate mismatch; score 4: mismatch. Soft tissue texture: assessment related to the smoother or rougher surface texture of the buccal peri-implant mucosa compared with natural gingiva at the contralateral tooth or the neighboring teeth. Score 1: match; score 2: slight mismatch; score 3: moderate mismatch; score 4: distinct mismatch. Soft tissue curvature: assessment according to the over-contoured or under-contoured buccal marginal peri-implant mucosa compared with natural gingiva at the contralateral tooth or the neighboring teeth. Score 1: match; score 2: slight mismatch; score 3: moderate mismatch; score 4: distinct mismatch. Alveolar process deficiency: assessment related to the concavity or convexity of the buccal peri-implant mucosa compared with the natural contour of the buccal gingiva at the contralateral tooth or the neighboring teeth. Score 1: match; score 2: slight mismatch; score 3: moderate mismatch; score 4: distinct mismatch. Marginal adaptation score: radiological assessment of fit or any gap between the implant crown and the abutment mesially and/or distally. Score 1: excellent fit; score 2: distinguishable misfit; score 3: distinct misfit; score 4: unacceptable misfit. Cement excess: radiographic presence (score 1) or absence (score 0) of cement in relation to the implant crowns. Kendall's Tau-b was used for comparisons between groups. McNemar's test was used for comparisons intragroups. Bold indicates statisically significant differences.

the mid-term. Consequently, reducing the implant diameter can be considered a valuable alternative treatment option to limit such sequelae, as suggested by the latest International Team of Implantology (ITI) Consensus Conference.[26]

It should be recalled that, despite the recent increased interest in peri-implant soft tissue conditions, particularly for aesthetic reasons,[27] peri-implant soft tissue augmentation procedures are recommended only in patients treated with dental implants in areas of aesthetic priority and with a thin soft tissue phenotype.[26,28,29]

This study has some limitations to be disclosed: first, it has to be pointed out that the primary outcome was set at the 1-year follow-up examination; therefore, the validity of the present 3-year data might

TABLE 3 Changes at frequency of aesthetic scores within the Ø2.9 mm and Ø3.3 mm groups (T2–T1, T3–T1 and T3–T2).

	T2–T1		T3–T1		T3–T2	
	Ø2.9 mm	Ø3.3 mm	Ø2.9 mm	Ø3.3 mm	Ø2.9 mm	Ø3.3 mm
	p-value	*p*-value	*p*-value	*p*-value	*p*-value	*p*-value
Symmetry/harmony	1.000	1.000	0.223	1.000	0.223	0.317
Soft tissue color	0.097	0.125	**0.004**	1.000	**0.014**	**0.005**
Papilla index (mesial)	1.000	0.146	1.000	0.788	1.000	1.000
Papilla index (distal)	0.063	0.882	0.754	0.625	**0.031**	1.000
Level of the margin	0.882	1.000	1.000	1.000	0.083	1.000
Soft tissue texture	**0.022**	0.125	0.581	1.000	0.063	1.000
Soft tissue curvature	0.219	1.000	1.000	0.500	0.125	0.500
Alveolar process deficiency	**0.031**	**0.030**	1.000	1.000	1.000	**0.029**
Cement excess (0/1)	0.250	1.000	0.250	1.000	1.000	1.000

Note: *p*-values obtained from McNemar's test for within-groups (T2–T1, T3–T1, T3–T2) comparisons. Bold indicates statisically significant differences.

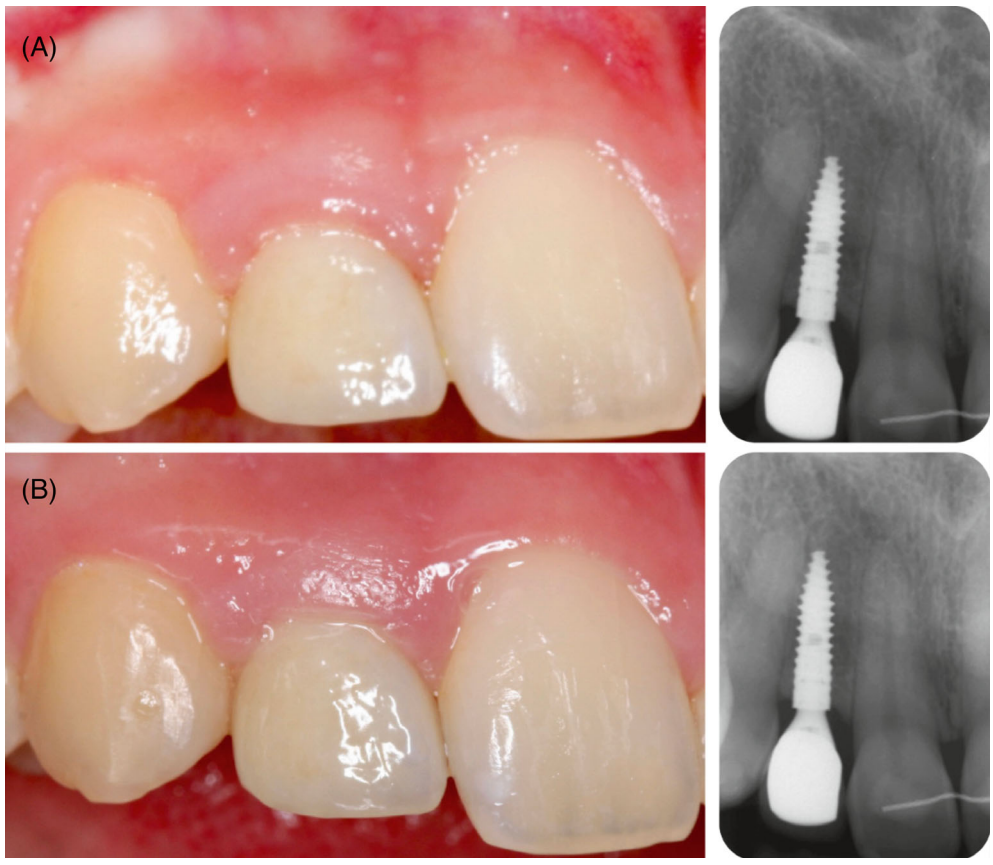

FIGURE 3 Clinical and radiographic presentation of a test implant at the 1-year (A) and 3-year (B) follow-up

be limited and affected by the high dropout rate (25%). One explanation of this high rate compared with similar studies is that all included patients were young subjects with high geographical mobility to study or pursue a career in another part of Denmark or abroad, making the 3-year assessment challenging. Furthermore, it should be recall that the present study could not be planned as a randomized controlled study and the consequently selection bias cannot be excluded. Second, at the time of study initiation (August 2016), the main focus of clinical research was on peri-implant hard tissue and consequently, a specific assessment of the coronal-apical peri-implant soft-tissue margin shift was not included. Nevertheless, the aesthetic assessment has provided indirect evidence of the peri-implant soft tissue conditions at all follow-up examinations (Figures 3–5). In addition, the radiographic assessment of the CBL changes was only performed at the mesial and distal implant surfaces, not providing information on facial-oral bone changes. However, due to ethical restrictions, a dedicated 3-D radiographic analysis was neither planned nor performed. Finally, tooth infraposition and changes in tooth-implant contact points were

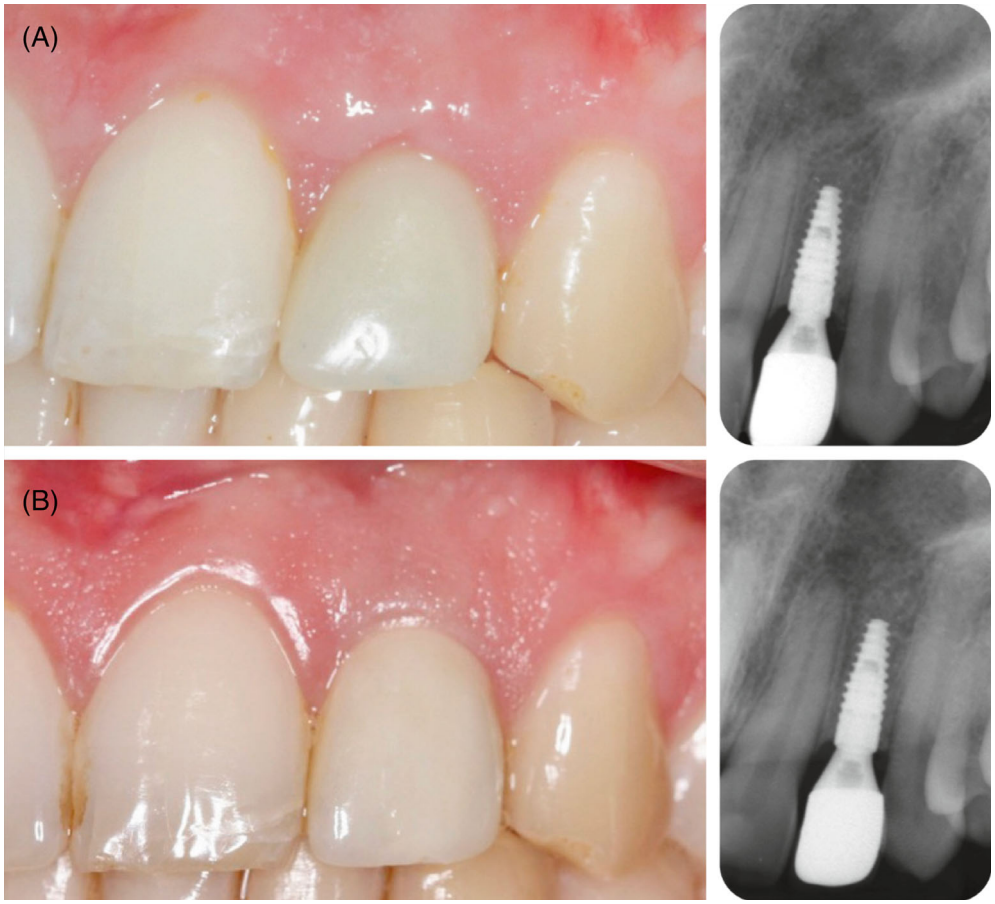

FIGURE 4 Clinical and radiographic presentation of a control implant at the 1-year (A) and 3-year (B) follow-up.

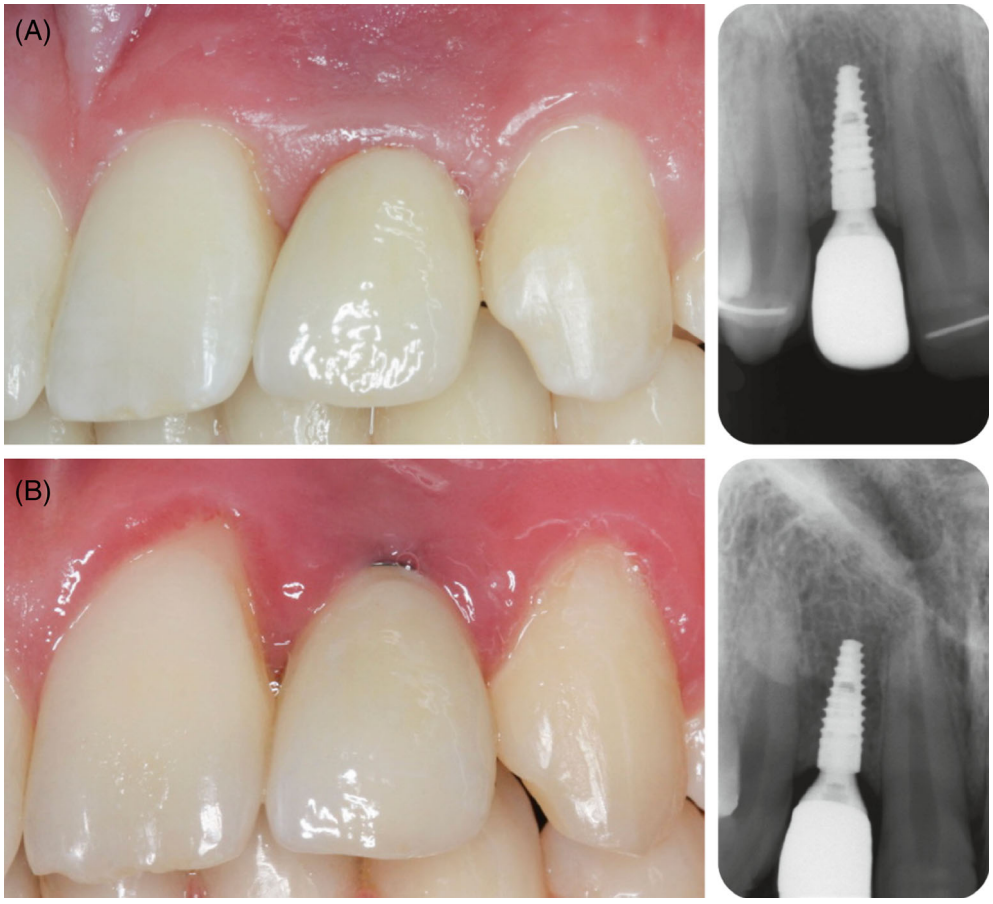

FIGURE 5 Clinical and radiographic presentation of an aesthetic complication developed between the 1-year (A) and 3-year (B) follow-up: apical shift of the peri-implant margin with consequent exposure of the Ti-abutment, alteration of the peri-implant soft-tissue texture and development of a gingival recession on the adjacent tooth in presence of sub-optimal plaque control.

not systematically evaluated. Nevertheless, the analysis of the clinical pictures showed no significant changes up to 3 years of loading.

In conclusion, despite the limitations of this study, the use of 2.9 mm or 3.3 mm diameter implants showed comparable and favorable mid-term results in terms of survival rate, CBL, and aesthetic outcomes. Clinicians can therefore rely on using such NDIs when replacing MLIs.

AUTHOR CONTRIBUTIONS

A.R. and S.S.J. conceived the idea and led the writing. S.S.J performed the surgeries. J.L. performed the prosthetics. A.R. and J.C.I. collected, analyzed, and interpreted the data. J.C.I and J.L. contributed to the writing.

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CONFLICT OF INTEREST STATEMENT

The authors declare no potential conflict of interests with respect to this study.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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