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Clinical and radiographic assessment of circular versus triangular cross-section neck Implants in the posterior maxilla: A 1-year randomized controlled trial

Lou Li Manni[1] | Geoffrey Lecloux[1] | Eric Rompen[1] | Walid Aouini[1,2] | Lior Shapira[3] | France Lambert[1,4]

[1]Department of Periodontology and Oral Surgery, University Hospital of Liège, Liège, Belgium

[2]Department of Periodontology, Faculty of Dental Medicine, Monastir, Tunisia

[3]Department of Periodontology, Hebrew University-Hadassah Faculty of Dental Medicine, Jerusalem, Israel

[4]Dental Biomaterials Research Unit, University of Liège, Liège, Belgium

Correspondence
France Lambert, Department of Periodontology and Oral Surgery, Domaine du Sart Tilman Bat B-35, B-4000 Liège, Belgique.
Email: france.lambert@chuliege.be

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Abstract

Objectives: Implants with a triangular neck were recently introduced to limit peri-implant bone loss. The primary objective of this randomized controlled trial was to compare peri-implant bone changes of circular versus triangular cross-section neck implants 1 year after loading. The secondary objectives were to assess buccal hard tissue thickness changes, Pink Esthetic Score (PES), and patient satisfaction.

Material and methods: Thirty four patients requiring replacement of the single, intercalated missing tooth of healed site for at least 4 months in the posterior maxilla were randomized into 2 groups according to the type of implant. Immediately after surgery and 1 year after final restoration, a cone beam CT (CBCT) was performed to assess proximal bone remodeling and buccal bone thickness. Peri-implant soft tissue health, PES, and patient-reported outcome measures (PROMs) were recorded.

Results: No implant loss occurred within the follow-up period. The mean ± *SD* peri-implant proximal bone loss 1 year after loading was 0.22 ± 0.30 mm for triangular and 0.42 ± 0.67 mm for circular implants necks (p = .25). Peri-implant bone loss exceeding 2 mm was observed in a single implant in the circular neck group. Buccal bone thickness remained stable and did not differ different between the 2 groups. The peri-implant soft tissue health, PES, and patient satisfaction were also comparable.

Conclusions: Within the limitations of the present study, patient clinical and radiographic outcomes did not differ between triangular and circular cross-section neck implants in the posterior maxilla.

KEYWORDS

buccal bone thickness, implant design, patient satisfaction, peri-implant bone remodeling, Pink Esthetic Score

Clinical trial registration number: NCT02591706

1 | INTRODUCTION

The success of dental implant osseointegration has been demonstrated over the last 50 years, and millions of patients have benefited from implant-supported oral rehabilitations (Berglundh, Persson, & Klinge, 2002; Pjetursson, Bragger, Lang, & Zwahlen, 2007). Currently, the main challenge is to maintain the stability of the peri-implant bone level over time and to prevent peri-implant disease (De Bruyn, Vandeweghe, Ruyffelaert, Cosyn, & Sennerby, 2013). Several factors can induce early peri-implant bone loss, including soft tissue thickness in the implant site (Akcali et al., 2017; van Eekeren, van Elsas, Tahmaseb, & Wismeijer, 2017), buccal bone thickness (Buser, Martin, & Belser, 2004; Spray, Black, Morris, & Ochi, 2000), repeated unscrewing of the transgingival components (Becker, Mihatovic, Golubovic, & Schwarz, 2012; Luongo et al., 2015; Rompen, 2012), undetected subgingival cement excess (Linkevicius, Puisys, Vindasiute, Linkeviciene, & Apse, 2013; Linkevicius, Vindasiute, et al., 2013; Linkevicius, Vindasiute, Puisys, & Peciuliene, 2011; Staubli, Walter, Schmidt, Weiger, & Zitzmann, 2017; Vindasiute et al., 2015), and design of the implant-abutment connection. The use of platform-switching implants has been widely suggested to limit early peri-implant bone loss (Al-Nsour, Chan, & Wang, 2012; Annibali et al., 2012; Atieh, Ibrahim, & Atieh, 2010; Santiago Jr. et al., 2016) in comparison with butt-joint connections (Sasada & Cochran, 2017).

An implant design with a triangular neck in its coronal portion was recently introduced to provide a better environment for the peri-implant bone. The triangular implant neck design leaves some spaces to provide a reservoir for blood supply and to offer compression-free areas reducing stress on the crestal bone, which ensures ideal conditions for osseointegration (Wiskott & Belser, 1999). Moreover, by placing the flat part of the neck in the buccal aspect, the buccal bone thickness would be enhanced. Finally, the triangular cross-section neck implant presents an internal conical connection that permits formation of an optimal seal against bacterial colonization (Caricasulo, Malchiodi, Ghensi, Fantozzi, & Cucchi, 2018) and allows platform switching. However, the potential benefit of this implant design has never been investigated clinically.

This randomized controlled trial was primarily designed to compare triangular and circular neck implants with respect to peri-implant bone changes 1 year after final restauration. It also purposed to assess for each type of implant the 1-year changes in buccal hard tissue thickness changes, esthetical aspects, peri-implant health, and patient-reported outcome measures (PROMS) in each group.

2 | MATERIALS AND METHODS

2.1 | Study design

This study was designed as a randomized controlled trial comparing two dental implants with different neck configurations: a conventional circular neck (C1, MIS Implants Technologies Ltd) versus a triangular cross-section neck (V3, MIS Implants Technologies Ltd; Figure 1).

A power calculation showed that with at least 32 patients included in the study (N = 16 in each group), a difference (Δ) in peri-implant bone loss of at least 0.50 mm between the two types of implants could be evidenced with a power of 80% and a significance level of 5% using a two-sided unpaired t test and assuming a standard deviation (SD) of bone losses of 0.50 mm. The final sample size was fixed at 34 patients to account for potential losses during the study.

Patients needing replacement of a single hopeless tooth in the posterior maxilla (premolar or molar) and seeking implant therapy were enrolled between March 2015 and January 2016 in the Department of Periodontology and Oral Surgery at the University of Liege, Belgium. Three experienced surgeons were involved in the surgical procedures. All clinical parameters and outcomes were recorded at implant placement (baseline), 4 months and 1 year after the final restoration, respectively. The study protocol was approved by

FIGURE 1 Comparison of implant design: circular neck on left (Cir group) and triangular neck on right (Tri group)

the Ethical Committee of the University Hospital of the University of Liège, Belgium (file number: B707201423142). The study was registered on clinicaltrial.gov (file number: NCT02591706) and performed according to the CONSORT statement for transparent reporting of randomized clinical trials (http://www.consort-statement.org/). The primary endpoint was the peri-implant bone change from baseline to 1 year post-insertion. Under the null hypothesis, there is no difference in peri-implant bone loss between test implants (triangular cross-section neck implant, Tri group) and control implants (conventional circular neck implant, Cir group).

2.2 | Study population

Each patient had to meet the following inclusion criteria: good general health (ASA I, II), 12-week healing period after extraction or loss of tooth, at least 10 mm and 6 mm of bone in the vertical and bucco-lingual dimensions, respectively, presence of at least 3 mm of keratinized mucosa at the implant site, aged >18 years old or with signed approval by parents or guardians, cigarette smoking status of <10 cigarettes per day, and signed informed consent. Exclusion criteria were as follows: use of bisphosphonate drugs intravenously, infection (local or systemic), uncontrolled diabetes, current breast-feeding, pregnancy, autoimmune disease that requires medical treatment, alcoholism, and immunodeficiency.

2.3 | Clinical procedures

2.3.1 | Pre-treatment evaluation

Prospective participants were screened for enrollment in the study according to the inclusion and exclusion criteria. Participants who complied with the inclusion criteria were enrolled in the study and were provided with written information concerning the study requirements and possible risks. Patients were examined clinically using a cone beam CT (CBCT) to ensure they complied with the requirements of the study.

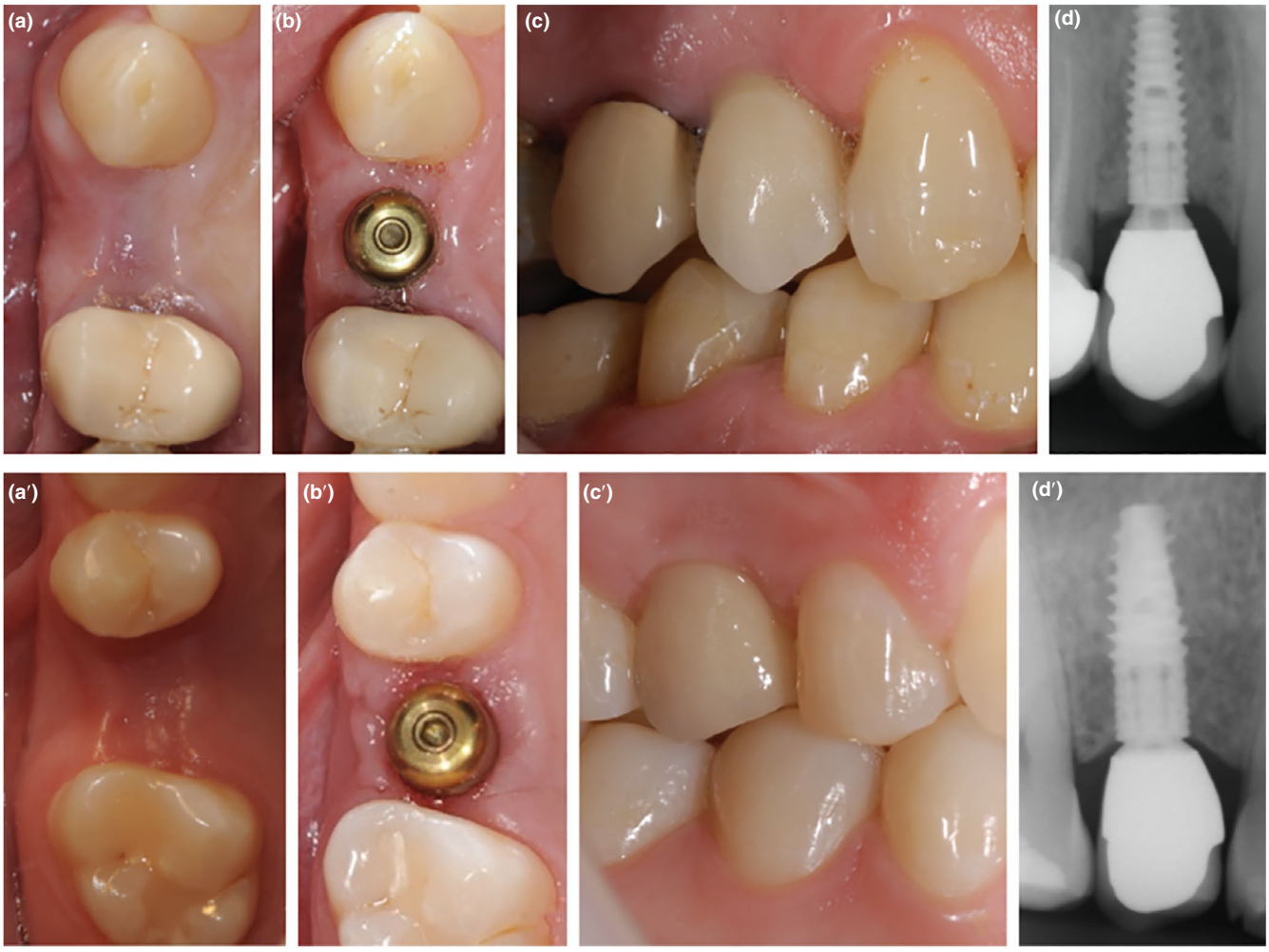

FIGURE 2 Clinical and radiographical images in each group: control: (a) pre-operative picture; (b) visit 10 to 14 days after surgery; 1-year follow-up: clinical view (c), 1-year radiographic control (d); test: (a') pre-operative picture; (b') visit 10 to 14 days after surgery; 1-year follow-up: clinical view (c'), 1-year radiographic control (d')

2.3.2 | Surgical procedures

All subjects received pre-operative antibiotic (amoxicillin 2 g, or if allergic, clindamycin, 600 mg). After local anesthesia, a supra-crestal incision was made in the edentulous area and full-thickness flaps were reflected to allow access to the site. The implantation procedure was carried out according to a standard surgical protocol and according to the manufacturers' protocol. Patients were randomly assigned to group Cir or Tri after flap opening using the software S-plus version 8.1 (TIBCO Software Inc.) and treated similarly. They remained unaware of the type of implant received throughout the study. The implant stability (insertion torque) was measured using the wrench key and the surgeons did not exceed an insertion torque higher than 45Ncm. Transgingival healing abutments were placed for a period of 4 months. The area was sutured with thin nylon sutures for a primary passive fit closure. Immediately after surgery, a calibrated CBCT was performed in the area of interest to assess baseline interproximal bone level and the buccal bone dimensions using a reduced field of view to cover the desired area at 0.2 mm voxel and using a reduced exposure protocol (Garib, Calil, Leal, & Janson, 2014).

2.3.3 | Post-operative instructions and follow-up

Patients were instructed to rinse twice daily with an aqueous solution of 0.2% chlorhexidine. In addition, analgesics (400 mg Ibuprofen up to 4/d) were prescribed for the next 2 days according to individual needs. Patients were also instructed to refrain from mechanical plaque removal in the area of implantation for 1 week. The sutures were removed after 10 to 14 days. After a healing period of 4 months, patients received restoration with screw-retained crowns made of Zirconia framework veneered with cosmetic ceramic. The crowns were bonded in the lab on titanium bases with adhesive resin composites (RelyX Ultimate®, 3M) of various heights according to the trans-mucosal thickness. The final visit was scheduled 1 year after the final restoration. At each appointment, patients received instructions to improve their oral hygiene if needed (Figure 2).

2.4 | Data collection

One single examiner performed all the radiographic and clinical assessments at 2 weeks and 4 months after the implant placement and then 1 year after final prosthesis installation. Each visit also included the evaluation of any change in the patient's dental or general history, patient's reported outcomes, and the Pink Esthetic Score (PES).

2.4.1 | Clinical assessment

All patient complaints or any complication occurrence, such as pain, paresthesia, or peri-implant infection, were recorded at each visit. At 4 months and 1 year after the implant loading, the peri-implant soft tissue health was assessed based on bleeding on probing (BOP); the sulcular modified bleeding index as described by Mombelli, van Oosten, Schürch, and Lang (1987) was also used to monitor the peri-implant inflammation. Additionally, the full mouth plaque score described by O'Leary, Drake, and Naylor (1972) was recorded. Lost implants were considered as implant failures directly affecting the implant survival rates.

2.4.2 | Radiographic assessments

Cone beam CT was performed just after implant insertion and then 1 year after the placement of the final restorations in order to calculate proximal marginal bone remodeling and the buccal bone dimensions, using the software Jaw Bone Quant 2012 (Medical Imaging Research Centre). Horizontal buccal bone thickness was measured on 3 points: 0, −2, and - 4 mm apically to the implant neck (Figure 3).

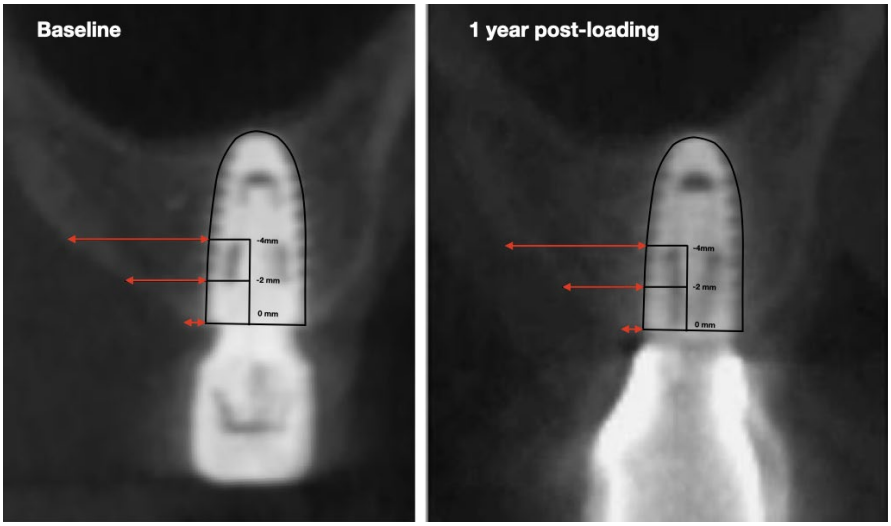

FIGURE 3 Buccal bone thickness measurements. (a) Baseline CBCT and (b). 1 year post-loading CBCT

2.4.3 | Pink Esthetic Score

Although initially described to evaluate the esthetic outcomes in the anterior region, the PES introduced by Furhauser et al. (2005) was used in the posterior region to assess the peri-implant soft tissue esthetic directly after the prosthetic procedures and 1 year after the final restoration. A score of 2, 1, or 0 was assigned to each PES parameters, yielding a maximum score of 14.

2.4.4 | Patient-reported outcome measures

Patient-related data were recorded using a self-reporting visual analog scale (VAS) questionnaire that employed a graduated scale of 0 to 10. The following parameter were collected at 1 week after the surgery or after 1 year: (a) pain level at implant placement (1 = low to 10 = high), (b) implant sensation compared with contralateral natural teeth (1 = not similar to 10 = very similar), (c) general esthetic result (1 = not satisfied to 10 = very satisfied), and (d) implant esthetic compared with contralateral natural teeth (1 = not similar to 10 = very similar). Additionally, the patients were asked if they would redo the treatment (1 = not at all to 10 = absolutely).

2.4.5 | Statistical analyses

Results were summarized as mean and standard deviation (*SD*) for quantitative variables and as frequency tables for categorical findings. Change between two time points was evaluated by a paired Student *t* test. Comparisons between groups were done using chi-square test for categorical findings and unpaired Student's *t* test for quantitative variables. Results were considered significant at the 5% significance level ($p < .05$). Data were analyzed with SAS version 9.4 (SAS Institute).

3 | RESULTS

3.1 | Patient characteristics

The CONSORT diagram (Figure 4) shows that 59 patients examined for potential inclusion in the study were needed to enroll the 34 eligible patients requested by the sample size calculation. The latter consisted of 24 (71%) women and 10 (29%) mean with a mean age of 47 years (range: 21–66 years). At baseline, the two groups were homogeneous with respect to demographics and implant-related characteristics (Table 1). All patients completed the 1-year follow-up study.

3.2 | Clinical outcomes

Surgical procedures for the 34 patients were performed according to the study protocol. Three implants (2 Cir and 1 Tri) out of 34 did not reach an insertion torque of at least 15 Ncm and were therefore submerged and uncovered after 3 months. The 34 implants were followed for a period of 1 year after the crown placement. No implant failed over the follow-up period, leading to an implant survival rate of 100%. Among the 34 evaluated implants, isolated bleeding on probing was found on 5 circular (41%) and 3 triangular neck (18%) implants, and no implant displayed spontaneous bleeding. The full

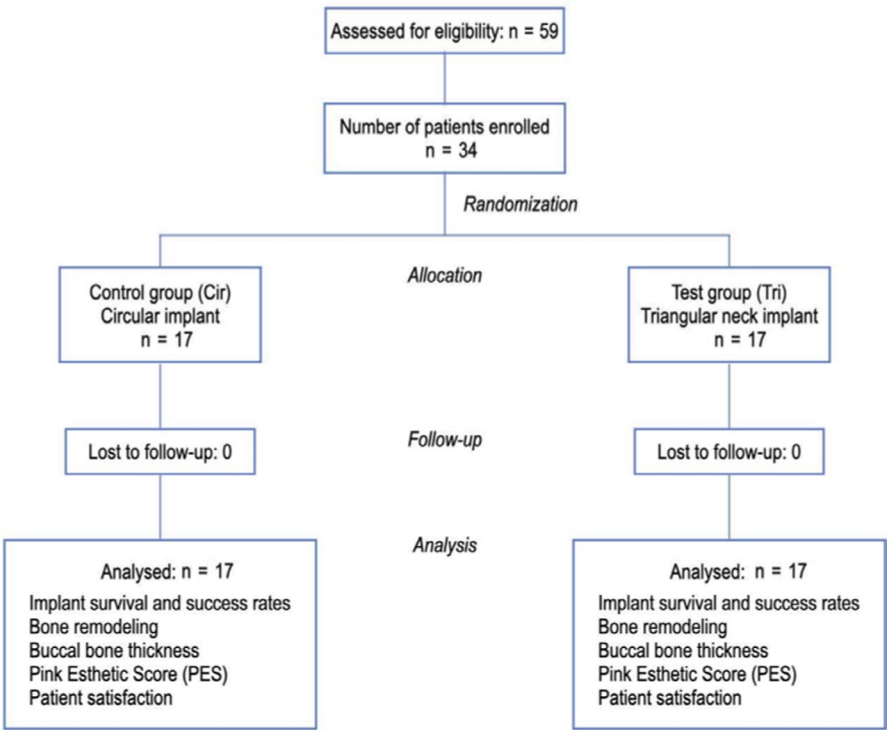

FIGURE 4 CONSORT flowchart

TABLE 1 Patient and implant-related characteristics

		Cir	Tri	
		n = 17		*p-value*
Patient				
Age (years) Mean ± *SD*		45.7 ± 10.4	46.8 ± 11.3	.77
Gender	Male	5	5	.99
	Female	12	12	
Implant				
Length (mm)	8	6	3	.45
	10	6	9	
	11.5	5	5	
Diameter (mm)	3.3	NA	1	.94
	3.75	4	NA	
	3.9	NA	6	
	4.2	10	NA	
	4.3	NA	7	
	5	3	3	
Torque	≤15 N/cm	2	1	.55
	> 15 N/cm	15	16	
Final drill	Yes	6	5	.99
	No	11	12	
Bone quality	1	0	0	.71
	2	1	0	
	3	12	11	
	4	4	6	
Tooth type	1st premolar	8	6	.60
	2nd premolar	2	5	
	1st molar	6	6	
	2nd molar	1	0	

TABLE 2 Peri-implant soft tissue health 1 year after implant loading

	Cir (*N* = 17)	Tri (*N* = 17)	*p-value*
Full mouth plaque scores at 1 year (%)	2	1	.99
Bleeding index scores			
No bleeding (0)	12	14	.69
Isolated bleeding (1)	5	3	
Confluent red line of blood on margins (2)	0	0	
Heavy or profuse bleeding (3)	0	0	

Note: Full mouth plaque score (FMPS): number of patients with a FMPS > 20%; Bleeding index according to Mombelli et al. (1987).

mouth plaque scores were acceptable over the follow-up as only 3 patients displayed a FMPS higher than 20%. Detailed peri-implant health results are displayed in Table 2.

3.3 | Radiographic outcomes

According to CBCT analyses, the mean proximal peri-implant bone loss (primary endpoint) from baseline to 1 year post-loading was 0.22 ± 0.30 mm for triangular neck implants and 0.42 ± 0.67 mm for circular implants. Both proximal peri-implant bone losses were statistically significant ($p < .05$) but no significant difference was observed between the 2 groups ($p = .25$); the mean group difference in peri-implant bone loss was 0.20 (95%CI −0.18 to 0.58) mm. Peri-implant bone loss exceeding 2 mm was observed in a single implant in the Cir group. Details are available in Table 3.

TABLE 3 Buccal hard tissue thickness changes and peri-implant bone remodeling over 1 year post-loading follow-up

			Cir (mean ± *SD*)	Tri (mean ± *SD*)	*p*-value
Peri-implant bone Remodeling (mm)	Mean ± *SD*		0.42 ± 0.67	0.22 ± 0.30	.25
	Range		0.0–2.81	0.0–0.79	
Buccal bone Thickness (mm)	Level 0	Baseline 1 year	1.34 ± 1.08 1.03 ± 1.05	1.34 ± 0.74 1.08 ± 0.72	.99 .86
		Baseline to 1-year changes	*p* = .52		
	Level −2	Baseline 1 year	1.93 ± 1.08 1.66 ± 0.93	1.84 ± 0.73 1.50 ± 0.74	.8 .59
		Baseline to 1-year changes	*p* = .38		
	Level −4	Baseline 1 year	1.94 ± 1.30 1.66 ± 1.23	1.75 ± 0.84 1.37 ± 0.77	.62 .43
		Baseline to 1-year changes	*p* = .32		

TABLE 4 Patient-related outcomes measures

Variable	*N*	Mean	*SD*	*p*-value
Pain at implant placement	34	1.41	0.657	
Cir	17	1.65	0.786	.035
Tri	17	1.18	0.393	
Implant feeling as a natural tooth	34	9.21	1.647	
Cir	17	9.06	1.819	.61
Tri	17	9.35	1.498	
General esthetic of the crown	34	9.68	0.727	
Cir	17	9.71	0.588	.82
Tri	17	9.65	0.862	
Esthetic of the crown similar to a natural tooth	34	9.59	0.743	
Cir	17	9.65	0.606	.65
Tri	17	9.53	0.874	
Redo the treatment?	34	9.97	0.171	
Cir	17	10.00	0.000	.32
Tri	17	9.94	0.243	

Note: Pain level at implant placement 1 = low to 10 = high; implant sensation compared with contralateral natural teeth: 1 = not similar to 10 = very similar; general esthetic result: 1 = not satisfied to 10 = very satisfied; implant esthetic compared with contralateral natural teeth: 1 = not similar to 10 = very similar. Patients were also asked if they would redo the treatment: 1 = not at all to 10 = absolutely.

3.4 | Buccal bone thickness

No difference between implants was observed in terms of buccal bone thickness at all measured levels (0, −2, and −4 mm) at baseline and thereafter as seen in Table 3.

3.5 | Pink Esthetic Score

Control and test groups were comparable for the overall PES scores (11.3 ± 2.4 for Tri group vs. 10.7 ± 1.8 for Cir group; $p = .44$) but also for each sub-domain scores.

3.6 | Patient-reported outcome measures

Patients from the two groups recognized a significant esthetic and comfort improvement from baseline to 1 year post-loading but no difference was evidenced between the two types of implants (Table 4).

4 | DISCUSSION

To our knowledge, this is the first randomized controlled trial aiming at comparing traditional and triangular neck shape implants in terms of peri-implant bone loss and other clinical outcomes.

4.1 | Peri-implant bone remodeling

After 1 year of loading, both implant designs yielded a 100% survival rate: On average, peri-implant bone loss was inferior to 0.5 mm and did not differ between the two types of implants. This minimal peri-implant bone remodeling is comparable with that described in the literature when using platform-switching implants (Al-Nsour et al., 2012; Atieh, Ibrahim, & Atieh, 2010; Canullo, Fedele, Iannello, & Jepsen, 2010; Santiago Jr. et al., 2016). The slightly lower peri-implant bone loss observed with triangular neck implants (0.22 mm as compared to 0.42 mm for conventional circular neck implants) is misleading and mainly due to a single circular neck implant exhibiting a bone loss as high as 2.8 mm. This loss could be the consequence of other confounding factors irrespective of the implant neck design.

For example, the insertion torque or the inconsistent height of the titanium bases may have an influence on crestal bone loss as described by some authors (Blanco et al., 2018; Galindo-Moreno et al., 2014, 2016; Novoa et al., 2017).

In the present study, the proximal peri-implant bone measurements at baseline and one year after loading were based on CBCT images because 3D imaging was performed for buccal bone thickness measurements anyway. Indeed, it has been shown that measurements of the peri-implant bone level on intraoral non-standardized X-rays can be distorted according to the angulation of the radiographic film (Benn, 1992; Malloy, Wadhwani, McAllister, Wang, & Katancik, 2017; Sewerin, 1990) and measurements by CBCT were considered more accurate by some authors (Pinsky, Dyda, Pinsky, Misch, & Sarment, 2006; Timock et al., 2011).

As suggested by recent European Federation of Periodontology consensus statements, peri-implant soft tissue health is an important criterion for implant success (Tonetti, Chapple, Jepsen, & Sanz, 2015), and bleeding on probing may be the first indicator of peri-implant disease such as mucositis or peri-implantitis (Jepsen et al., 2015; Jepsen, Ruhling, Jepsen, Ohlenbusch, & Albers, 1996; Lang, Berglundh, & Working Group 4 of Seventh European Workshop on Periodontology, 2011; Lindhe, Meyle, & Group D of European Workshop on Periodontology, 2008). In the present study, after 1 year of loading, most implants displayed healthy peri-implant soft tissues, an isolated bleeding was observed in 23% of the tested implants, which is less than the 50% reported by Lindhe et al. (2008). However, bleeding on probing should be interpreted carefully since the force exerted on the probe is operator-dependent and probing around an implant is more sensitive than around a natural tooth and could cause false evaluations of positive bleeding on probing (Gerber, Tan, Balmer, Salvi, & Lang, 2009).

The esthetic of the peri-implant soft tissue is also a critical parameter for implant success especially since patient expectations tend to increase even in the posterior region of the maxilla when they show up to the first molar when smiling. Moreover, the PES described by Furhauser et al. (2005) is a reproducible tool to assess soft tissue quality in the esthetic area which can be also used to monitor soft tissue quality over time, one reason why it was decided to use it for the posterior region considered in the present study.

The PES was high for both groups, and the variable with the lowest score was generally the alveolar process resorption, which is related to centripetal bone resorption after extraction at the upper maxilla. Indeed, the study criteria excluded previous ridge preservation techniques or extraction and immediate implants that may have limited this buccal bone remodeling (Lambert et al., 2012; Tan, Wong, Wong, & Lang, 2012; Tomlin, Nelson, & Rossmann, 2014; Vanhoutte et al., 2014). Also, the score related to the papilla is dependent on the anatomy of the bone level of the adjacent teeth and anatomy (Choquet et al., 2001; Tarnow, Magner, & Fletcher, 1992). These parameters are not related to the implant design, and therefore, data should be interpreted cautiously.

Considering not only the peri-implant bone remodeling but also the bleeding on probing and the PES, the clinical outcomes after 1 year of implant loading showed that the triangular cross-section neck implants resulted in similar outcomes compared with the circular implants; however, longer follow-up would be needed to confirm this tendency. Also, the present results are valid for the posterior maxilla only and further studies should be performed to assert similar conclusions for the mandible and for the esthetic zone. Indeed, the maxilla displays a better blood supply than the mandible and implants placed in a more cortical bone may behave differently, although the literature to support that is scanty (Tolstunov, 2007).

4.2 | Buccal bone thickness

Although there is no clinical evidence, the buccal bone thickness at the implant site is often claimed as key factor for long-term success and for preventing buccal recession (Buser et al., 2004; Temmerman, Keestra, Coucke, Teughels, & Quirynen, 2015). One of the presumed advantages of the triangular neck implant is that the buccal off shift leaves more space for buccal bone; it would consequently prevent buccal recession. However, the present results did not show any difference in buccal bone thickness between the 2 groups at baseline. However, the distance from the buccal bone to the first drilling point was not calibrated which may have led to a heterogeneous bucco-lingual position. This limitation should be considered, and therefore, the results should be interpreted carefully. Moreover, it should also be emphasized that all implants of the present trial were placed in the posterior upper maxilla and the features of the triangular neck implant may be more relevant in the anterior zone of the maxilla where recession could lead to esthetic problems.

4.3 | Patient-reported outcomes

According to some authors, patient-reported outcomes should also be considered for reporting on implant success (De Bruyn, Raes, Matthys, & Cosyn, 2015; Levi, Psoter, Agar, Reisine, & Taylor, 2003; Tey, Phillips, & Tan, 2017). In the present study, all of the 34 patients were quite satisfied by the implant treatment they received for the replacement of a single missing tooth. All were pleased with the esthetic aspect of their crown, the level of comfort when chewing, and all would recommend such treatment to their family and friends. However, there are few controlled studies about patient-centered outcomes for single implant therapy since no recommendation exists (De Bruyn et al., 2015). The satisfaction questionnaire in the present study might be useful in the absence of other tools to assess patient-reported outcomes for single tooth replacement with an implant. Moreover, in the present study, enrolled patients required only a straightforward implant therapy without any additional surgery: The degree of overall satisfaction could therefore have been positively influenced in comparison

with a more complex treatment requiring, for example, bone grafting (Cosyn et al., 2013). Finally, these data have to be interpreted cautiously since patients were aware of their participation in a study in which they had a financial benefit, which could have influenced their overall satisfaction.

5 | CONCLUSION

Within the limitations of the present study, circular and triangular cross-section neck implants in the posterior maxilla were similar with respect to peri-implant bone changes. The implant neck design did not impact the pink aesthetic score and the patient satisfaction. These findings should be re-evaluated after a longer follow-up period to confirm the long-term performance of triangular neck design implants, as well as on a larger number of patients.

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AUTHOR CONTRIBUTIONS

FL, ER and LS conceived the ideas; GL, LLM and WA collected the data; LLM and WA analyzed the data; and FL led the writing.

ORCID

Lior Shapira https://orcid.org/0000-0001-9145-5155
France Lambert https://orcid.org/0000-0002-1018-2544

REFERENCES

Akcali, A., Trullenque-Eriksson, A., Sun, C., Petrie, A., Nibali, L., & Donos, N. (2017). What is the effect of soft tissue thickness on crestal bone loss around dental implants? A systematic review. *Clinical Oral Implants Research*, *28*(9), 1046–1053. https://doi.org/10.1111/clr.12916

Al-Nsour, M. M., Chan, H. L., & Wang, H. L. (2012). Effect of the platform-switching technique on preservation of peri-implant marginal bone: A systematic review. *International Journal of Oral and Maxillofacial Implants*, *27*(1), 138–145. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/22299090

Annibali, S., Bignozzi, I., Cristalli, M. P., Graziani, F., La Monaca, G., & Polimeni, A. (2012). Peri-implant marginal bone level: A systematic review and meta-analysis of studies comparing platform switching versus conventionally restored implants. *Journal of Clinical Periodontology*, *39*(11), 1097–1113. https://doi.org/10.1111/j.1600-051X.2012.01930.x

Atieh, M. A., Ibrahim, H. M., & Atieh, A. H. (2010). Platform switching for marginal bone preservation around dental implants: A systematic review and meta-analysis. *Journal of Periodontology*, *81*(10), 1350–1366. https://doi.org/10.1902/jop.2010.100232

Becker, K., Mihatovic, I., Golubovic, V., & Schwarz, F. (2012). Impact of abutment material and dis-/re-connection on soft and hard tissue changes at implants with platform-switching. *Journal of Clinical Periodontology*, *39*(8), 774–780. https://doi.org/10.1111/j.1600-051X.2012.01911.x

Benn, D. K. (1992). Estimating the validity of radiographic measurements of marginal bone height changes around osseointegrated implants. *Implant Dent*, *1*(1), 79–83. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/1288800

Berglundh, T., Persson, L., & Klinge, B. (2002). A systematic review of the incidence of biological and technical complications in implant dentistry reported in prospective longitudinal studies of at least 5 years. *Journal of Clinical Periodontology*, *29*(s3), 197–212. https://doi.org/10.1034/j.1600-051X.29.s3.12.x

Blanco, J., Pico, A., Caneiro, L., Novoa, L., Batalla, P., & Martin-Lancharro, P. (2018). Effect of abutment height on interproximal implant bone level in the early healing: A randomized clinical trial. *Clinical Oral Implants Research*, *29*(1), 108–117. https://doi.org/10.1111/clr.13108

Buser, D., Martin, W., & Belser, U. C. (2004). Optimizing esthetics for implant restorations in the anterior maxilla: Anatomic and surgical considerations. *International Journal of Oral and Maxillofacial Implants*, *19*(Suppl), 43–61. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/15635945

Canullo, L., Fedele, G. R., Iannello, G., & Jepsen, S. (2010). Platform switching and marginal bone-level alterations: The results of a randomized-controlled trial. *Clinical Oral Implants Research*, *21*(1), 115–121. https://doi.org/10.1111/j.1600-0501.2009.01867.x

Caricasulo, R., Malchiodi, L., Ghensi, P., Fantozzi, G., & Cucchi, A. (2018). The influence of implant-abutment connection to peri-implant bone loss: A systematic review and meta-analysis. *Clinical Implant Dentistry and Related Research*, *20*(4), 653–664. https://doi.org/10.1111/cid.12620

Choquet, V., Hermans, M., Adriaenssens, P., Daelemans, P., Tarnow, D. P., & Malevez, C. (2001). Clinical and radiographic evaluation of the papilla level adjacent to single-tooth dental implants. A retrospective study in the maxillary anterior region. *Journal of Periodontology*, *72*(10), 1364–1371. https://doi.org/10.1902/jop.2001.72.10.1364

Cosyn, J., Eghbali, A., Hanselaer, L., De Rouck, T., Wyn, I., Sabzevar, M. M., … De Bruyn, H. (2013). Four modalities of single implant treatment in the anterior maxilla: A clinical, radiographic, and aesthetic evaluation. *Clinical Implant Dentistry and Related Research*, *15*(4), 517–530. https://doi.org/10.1111/j.1708-8208.2011.00417.x

De Bruyn, H., Raes, S., Matthys, C., & Cosyn, J. (2015). The current use of patient-centered/reported outcomes in implant dentistry: A systematic review. *Clinical Oral Implants Research*, *26*(Suppl 11), 45–56. https://doi.org/10.1111/clr.12634

De Bruyn, H., Vandeweghe, S., Ruyffelaert, C., Cosyn, J., & Sennerby, L. (2013). Radiographic evaluation of modern oral implants with emphasis on crestal bone level and relevance to peri-implant health. *Periodontology 2000*, *62*(1), 256–270. https://doi.org/10.1111/prd.12004.

Furhauser, R., Florescu, D., Benesch, T., Haas, R., Mailath, G., & Watzek, G. (2005). Evaluation of soft tissue around single-tooth implant crowns: The pink esthetic score. *Clinical Oral Implants Research*, *16*(6), 639–644. https://doi.org/10.1111/j.1600-0501.2005.01193.x

Galindo-Moreno, P., Leon-Cano, A., Monje, A., Ortega-Oller, I., O'Valle, F., & Catena, A. (2016). Abutment height influences the effect of platform switching on peri-implant marginal bone loss. *Clinical Oral Implants Research*, *27*(2), 167–173. https://doi.org/10.1111/clr.12554

Galindo-Moreno, P., León-Cano, A., Ortega-Oller, I., Monje, A., Suárez, F., ÓValle, F., … Catena, A. (2014). Prosthetic abutment height is a key factor in peri-implant marginal bone loss. *Journal of Dental Research*, *93*(7 Suppl), 80S–85S. https://doi.org/10.1177/0022034513519800

Garib, D. G., Calil, L. R., Leal, C. R., & Janson, G. (2014). Is there a consensus for CBCT use in Orthodontics? *Dental Press Journal of Orthodontics*, *19*(5), 136–149.https://doi.org/10.1590/2176-9451.19.5.136-149.sar

Gerber, J. A., Tan, W. C., Balmer, T. E., Salvi, G. E., & Lang, N. P. (2009). Bleeding on probing and pocket probing depth in relation to probing pressure and mucosal health around oral implants. *Clinical Oral Implants Research*, *20*(1), 75–78. https://doi.org/10.1111/j.1600-0501.2008.01601.x

Jepsen, S., Berglundh, T., Genco, R., Aass, A. M., Demirel, K., Derks, J., … Zitzmann, N. U. (2015). Primary prevention of peri-implantitis: Managing peri-implant mucositis. *Journal of Clinical Periodontology*, *42*(Suppl 16), S152–S157. https://doi.org/10.1111/jcpe.12369

Jepsen, S., Ruhling, A., Jepsen, K., Ohlenbusch, B., & Albers, H. K. (1996). Progressive peri-implantitis. Incidence and prediction of peri-implant attachment loss. *Clinical Oral Implants Research*, *7*(2), 133–142 Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/9002832

Lambert, F., Vincent, K., Vanhoutte, V., Seidel, L., Lecloux, G., & Rompen, E. (2012). A methodological approach to assessing alveolar ridge preservation procedures in humans: Hard tissue profile. *Journal of Clinical Periodontology*, *39*(9), 887–894. https://doi.org/10.1111/j.1600-051X.2012.01900.x

Lang, N. P., & Berglundh, T., & Working Group 4 of Seventh European Workshop on Periodontology. (2011). Periimplant diseases: Where are we now? – Consensus of the Seventh European Workshop on Periodontology. *Journal of Clinical Periodontology*, *38*(Suppl 11), 178–181. https://doi.org/10.1111/j.1600-051X.2010.01674.x

Levi, A., Psoter, W. J., Agar, J. R., Reisine, S. T., & Taylor, T. D. (2003). Patient self-reported satisfaction with maxillary anterior dental implant treatment. *International Journal of Oral and Maxillofacial Implants*, *18*(1), 113–120. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/12608676

Lindhe, J., & Meyle, J., & Group D of European Workshop on Periodontology. (2008). Peri-implant diseases: Consensus report of the sixth European workshop on periodontology. *Journal of Clinical Periodontology*, *35*(8 Suppl), 282–285. https://doi.org/10.1111/j.1600-051X.2008.01283.x

Linkevicius, T., Puisys, A., Vindasiute, E., Linkeviciene, L., & Apse, P. (2013). Does residual cement around implant-supported restorations cause peri-implant disease? A retrospective case analysis. *Clinical Oral Implants Research*, *24*(11), 1179–1184. https://doi.org/10.1111/j.1600-0501.2012.02570.x

Linkevicius, T., Vindasiute, E., Puisys, A., Linkeviciene, L., Maslova, N., & Puriene, A. (2013). The influence of the cementation margin position on the amount of undetected cement. A prospective clinical study. *Clinical Oral Implants Research*, *24*(1), 71–76. https://doi.org/10.1111/j.1600-0501.2012.02453.x

Linkevicius, T., Vindasiute, E., Puisys, A., & Peciuliene, V. (2011). The influence of margin location on the amount of undetected cement excess after delivery of cement-retained implant restorations. *Clinical Oral Implants Research*, *22*(12), 1379–1384. https://doi.org/10.1111/j.1600-0501.2010.02119.x

Luongo, G., Bressan, E., Grusovin, M. G., d'Avenia, F., Neumann, K., Sbricoli, L., & Esposito, M. (2015). Do repeated changes of abutments have any influence on the stability of peri-implant tissues? Four-month post-loading preliminary results from a multicentre randomised controlled trial. *European Journal of Oral Implantology*, *8*(2), 129–140. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/26021224

Malloy, K. A., Wadhwani, C., McAllister, B., Wang, M., & Katancik, J. A. (2017). Accuracy and reproducibility of radiographic images for assessing crestal bone height of implants using the precision implant X-ray locator (PIXRL) device. *International Journal of Oral and Maxillofacial Implants*, *32*(4), 830–836. https://doi.org/10.11607/jomi.5683

Mombelli, A., van Oosten, M. A. C., Schürch, E., & Lang, N. P. (1987). The microbiota associated with successful or failing osseointegrated titanium implants. *Oral Microbiology and Immunology*, *2*(4), 145–151. https://doi.org/10.1111/j.1399-302X.1987.tb00298.x

Novoa, L., Batalla, P., Caneiro, L., Pico, A., Linares, A., & Blanco, J. (2017). Influence of abutment height on maintenance of peri-implant crestal bone at bone-level implants: A 3-year follow-up study. *The International Journal of Periodontics & Restorative Dentistry*, *37*(5), 721–727. https://doi.org/10.11607/prd.2762

O'Leary, T. J., Drake, R. B., & Naylor, J. E. (1972). The plaque control record. *Journal of Periodontology*, *43*(1), 38. https://doi.org/10.1902/jop.1972.43.1.38

Pinsky, H. M., Dyda, S., Pinsky, R. W., Misch, K. A., & Sarment, D. P. (2006). Accuracy of three-dimensional measurements using cone-beam CT. *Dentomaxillofacial Radiology*, *35*(6), 410–416. https://doi.org/10.1259/dmfr/20987648

Pjetursson, B. E., Bragger, U., Lang, N. P., & Zwahlen, M. (2007). Comparison of survival and complication rates of tooth-supported fixed dental prostheses (FDPs) and implant-supported FDPs and single crowns (SCs). *Clinical Oral Implants Research*, *18*(Suppl 3), 97–113. https://doi.org/10.1111/j.1600-0501.2007.01439.x

Rompen, E. (2012). The impact of the type and configuration of abutments and their (repeated) removal on the attachment level and marginal bone. *European Journal of Oral Implantology*, *5*(Suppl), S83–90. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/22834397

Santiago Jr., J. F., Batista, V. E., Verri, F. R., Honorio, H. M., de Mello, C. C., Almeida, D. A., & Pellizzer, E. P. (2016). Platform-switching implants and bone preservation: A systematic review and meta-analysis. *International Journal of Oral and Maxillofacial Surgery*, *45*(3), 332–345. https://doi.org/10.1016/j.ijom.2015.11.009

Sasada, Y., & Cochran, D. L. (2017). Implant-abutment connections: A review of biologic consequences and peri-implantitis implications. *International Journal of Oral and Maxillofacial Implants*, *32*(6), 1296–1307. https://doi.org/10.11607/jomi.5732

Sewerin, I. P. (1990). Errors in radiographic assessment of marginal bone height around osseointegrated implants. *Scandinavian Journal of Dental Research*, *98*(5), 428–433. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/2293349

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

Staubli, N., Walter, C., Schmidt, J. C., Weiger, R., & Zitzmann, N. U. (2017). Excess cement and the risk of peri-implant disease – A systematic review. *Clinical Oral Implants Research*, *28*(10), 1278–1290. https://doi.org/10.1111/clr.12954

Tan, W. L., Wong, T. L., Wong, M. C., & Lang, N. P. (2012). A systematic review of post-extractional alveolar hard and soft tissue dimensional changes in humans. *Clinical Oral Implants Research*, *23*(Suppl 5), 1–21. https://doi.org/10.1111/j.1600-0501.2011.02375.x

Tarnow, D. P., Magner, A. W., & Fletcher, P. (1992). The effect of the distance from the contact point to the crest of bone on the presence or absence of the interproximal dental papilla. *Journal of Periodontology*, *63*(12), 995–996. https://doi.org/10.1902/jop.1992.63.12.995

Temmerman, A., Keestra, J. A. J., Coucke, W., Teughels, W., & Quirynen, M. (2015). The outcome of oral implants placed in bone with limited bucco-oral dimensions: A 3-year follow-up study. *Journal of Clinical Periodontology*, *42*, 311–318. https://doi.org/10.1111/jcpe.12376

Tey, V. H. S., Phillips, R., & Tan, K. (2017). Patient-related outcome measures with implant therapy after 5 years. *Clinical Oral Implants Research*, *28*(6), 683–688. https://doi.org/10.1111/clr.12862

Timock, A. M., Cook, V., McDonald, T., Leo, M. C., Crowe, J., Benninger, B. L., & Covell, D. A. Jr (2011). Accuracy and reliability of buccal bone height and thickness measurements from cone-beam computed tomography imaging. *American Journal of Orthodontics and Dentofacial Orthopedics*, *140*(5), 734–744. https://doi.org/10.1016/j.ajodo.2011.06.021

Tolstunov, L. (2007). Implant zones of the jaws: Implant location and related success rate. *Journal of Oral Implantology*, *33*(4), 211–220. https://doi.org/10.1563/1548-1336(2007)33[211:IZOTJI]2.0.CO;2

Tomlin, E. M., Nelson, S. J., & Rossmann, J. A. (2014). Ridge preservation for implant therapy: A review of the literature. *The Open Dentistry Journal*, *8*, 66–76. https://doi.org/10.2174/1874210601408010066

Tonetti, M. S., Chapple, I. L., Jepsen, S., & Sanz, M. (2015). Primary and secondary prevention of periodontal and peri-implant diseases: Introduction to, and objectives of the 11th European Workshop on Periodontology consensus conference. *Journal of Clinical Periodontology*, *42*(Suppl 16), S1–S4. https://doi.org/10.1111/jcpe.12382

van Eekeren, P., van Elsas, P., Tahmaseb, A., & Wismeijer, D. (2017). The influence of initial mucosal thickness on crestal bone change in similar macrogeometrical implants: A prospective randomized clinical trial. *Clinical Oral Implants Research*, *28*(2), 214–218. https://doi.org/10.1111/clr.12784

Vanhoutte, V., Rompen, E., Lecloux, G., Rues, S., Schmitter, M., & Lambert, F. (2014). A methodological approach to assessing alveolar ridge preservation procedures in humans: Soft tissue profile. *Clinical Oral Implants Research*, *25*(3), 304–309. https://doi.org/10.1111/clr.12144

Vindasiute, E., Puisys, A., Maslova, N., Linkeviciene, L., Peciuliene, V., & Linkevicius, T. (2015). Clinical factors influencing removal of the cement excess in implant-supported restorations. *Clinical Implant Dentistry and Related Research*, *17*(4), 771–778. https://doi.org/10.1111/cid.12170

Wiskott, H. W., & Belser, U. C. (1999). Lack of integration of smooth titanium surfaces: A working hypothesis based on strains generated in the surrounding bone. *Clinical Oral Implants Research*, *10*(6), 429–444. https://doi.org/10.1034/j.1600-0501.1999.100601.x

SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

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