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Short-term outcomes of lateral extraction socket augmentation using autogenous tooth roots: A prospective observational study

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Abstract

Objectives: To assess the short-term clinical outcomes of lateral augmentation of deficient extraction sockets and two-stage implant placement using autogenous tooth roots (TR).

Material and methods: A total of $n = 13$ patients (13 implants) were available for the analysis. At the time of tooth extraction, each subject had received lateral augmentation using the respective non-retainable but non-infected tooth root where the thickness of the buccal bone was <0.5 mm or where a buccal dehiscence-type defect was present. Titanium implants were placed after a submerged healing period of 6 months and loaded after 20 ± 2 weeks (V8). Clinical parameters (e.g., bleeding on probing—BOP, probing pocket depth—PD, mucosal recession—MR, clinical attachment level—CAL) were recorded at V8 and after 26 ± 4 weeks (V9) of implant loading.

Results: At V9, all patients investigated revealed non-significant changes in mean BOP (−19.23 ± 35.32%), PD (0.24 ± 0.49 mm), MR (0.0 ± 0.0 mm) and CAL (0.24 ± 0.49 mm) values, respectively. There was no significant correlation between the initial gain in ridge width and changes in BOP and PD values.

Conclusions: The surgical procedure was associated with stable peri-implant tissues on the short-term.

KEYWORDS

alveolar ridge augmentation, clinical study, tooth autotransplantation

1 | INTRODUCTION

The management of extraction sockets has become a topic of major clinical relevance in contemporary implant dentistry (Avila-Ortiz, Chambrone, & Vignoletti, 2019). In fact, tooth extraction triggers a cascade of biological events leading to substantial dimensional changes of the alveolar ridge during the first 6 months of healing (Tan, Wong, Wong, & Lang, 2012). These changes are more pronounced at the buccal aspect (Araujo, Silva, Misawa, & Sukekava, 2015; Botticelli, Berglundh, & Lindhe, 2004) and intensified in the presence of a compromised extraction socket. In particular, the presence of a severe bone loss at the time of extraction resulted in a slower

[Correction added on 30 July 2020, after the first online publication: Projekt Deal funding statement has been added.]

TABLE 1 (a) Patient characteristics (refers to Visit 7). (b) Reasons for tooth extraction and numbers (refers to Visit 2)

(a)	
Patient age	50.0 ± 7.5 years; range: 34–58 years
Female/male	*n* = 7/6
Subgroup—insufficient bone thickness	*n* = 8
Subgroup—dehiscence-type defect	*n* = 5
(b)	
Substantial loss of the clinical crown	*n* = 10 (6 with endodontic treatment)
Fractured teeth	*n* = 2
Advanced periodontal destruction due to occlusal trauma	*n* = 1

healing and cortication (Ahn & Shin, 2008; Bertl et al., 2018) as well as a greater volume reduction when compared with intact extraction sites (Aimetti et al., 2018). Moreover, the vertical bone loss was significantly higher at extraction sites exhibiting a thin buccal bone thickness (<1 mm) when compared with sites exhibiting a bone thickness of 1 mm or more (7.5 mm [62%] vs. 1.1 mm [9%], respectively) (Chappuis et al., 2013).

The results of a recent prospective observational study have indicated that the usage of autogenous tooth roots (TR) may represent a feasible approach for lateral augmentation of deficient extraction sockets and two-stage implant placement (Schwarz, Sahin, Becker, Sader, & Becker, 2019). In particular, the surgical procedure included a simultaneous, lateral augmentation of deficient (i.e., thickness of the buccal bone <0.5 mm or buccal dehiscence-type defects) fresh extraction sockets using the respective non-retainable but non-infected teeth. After 26 weeks of submerged healing, the change in ridge width amounted to 4.89 ± 2.29 mm and allowed for a successful implant placement in all patients investigated (Schwarz et al., 2019). The basic concept was based on previous findings of a series of experimental studies indicating that TR have a biological potential to sever as alternative grafts for localized alveolar ridge augmentation (Schwarz, Golubovic, Becker, & Mihatovic, 2016; Schwarz, Golubovic, Mihatovic, & Becker, 2016; Schwarz, Schmucker, & Becker, 2016).

The aim of the present study was to assess the short-term clinical outcomes of lateral augmentation of deficient extraction sockets and two-stage implant placement using TR.

2 | MATERIAL AND METHODS

2.1 | Study design and participants

A total of 15 patients each exhibiting one non-retainable but non-infected tooth attended the Department of Oral Surgery at the Heinrich Heine University Düsseldorf, Germany and had received a lateral augmentation of a deficient fresh extraction socket (i.e., either an insufficient thickness of the buccal bone <0.5 mm or the presence of a buccal dehiscence-type defect) using the respective TR. After 26 weeks of submerged healing, a re-entry was performed and implants had been placed at the respective sites. The primary outcome was defined as the crestal ridge width (mm) (CW26) being sufficient to place an adequately dimensioned titanium implant. The secondary outcome was the gain in ridge width (CWg), which was calculated as CW26—CW measured immediately before augmentation. These data have been published recently (Schwarz et al., 2019).

At 9–20 weeks after implant placement, implant loading was accomplished and clinical baseline data were recorded. The present analysis focused on the changes in clinical outcomes assessed after 26 ± 4 weeks of implant loading. The study outline and the follow-up visits are summarized in Table 2. Due to lost to follow-up, *n* = 13 patients exhibiting a total of *n* = 13 implants were available for the present analysis. The patient characteristics and reasons for tooth extraction are presented in Table 1a,b. The study protocol was approved by the ethics committee of the Heinrich Heine University, Düsseldorf and registered via the Internet Portal of the German Clinical Trials Register (DRKS00009586). Each patient was given a detailed description of the study procedures and signed an informed consent before participation. The present reporting considered the checklist items as proposed in the STROBE statement.

2.2 | Sample size calculation

Due to the proof-of-principle character of the present observational study and a lack of similar data in the literature, a sample size calculation was not feasible. However, the initial sample size of *n* = 15 was considered to be sufficient to allow for a first evaluation of the efficacy (i.e., CWg at 26 weeks) of the presented surgical procedure.

TABLE 2 Study design and follow-up visits (D = day; W = week)

Visit 1	Visit 2	Visit 3	Visit 4	Visit 5	Visit 6	Visit 7	Visit 8	Visit 9
Enrollment	Surgery	SR			R/IP	SR	IL, CM	CM
	D0	D10	W4	W13	W26	D10 ± 4 post V6	W9–20 ± 2 post V7	W26 ± 4 post V8

Note: Visit 1: patient enrollment. Visit 2: lateral ridge augmentation using TR. Visit 3: SR = suture removal. Visits 4/5: follow-up visits. Visit 6: R = re-entry/IP = implant placement. Visit 7: SR. Visit 8: IL = implant loading; CM = clinical measurements of baseline data. Visit 9: CM = clinical measurements of follow-up data.

2.3 | Inclusion and exclusion criteria

Patients were initially included in the study if they presented all of the following conditions: (a) Age 18–60 years, (b) candidate for lateral ridge augmentation, (c) insufficient bone ridge width at the recipient site for implant placement, (d) sufficient bone height at the recipient site for implant placement, and (e) healthy oral mucosa, at least 3 mm keratinized tissue.

The patients were not included in the study if they presented one of the following conditions: (a) general contraindications for dental and/or surgical treatments, (b) inflammatory and autoimmune disease of the oral cavity, (c) uncontrolled diabetes (HbA1c > 7%), (d) history of malignancy requiring chemotherapy or radiotherapy within the past 5 years, (e) previous immunosuppressant, bisphosphonate or high dose corticosteroid therapy, (f) smokers, (g) pregnant or lactating women (Schwarz, Schmucker, & Becker, 2016).

2.4 | Surgical procedures

The surgical procedures have been reported in detail previously (Schwarz et al., 2019).

In brief, TR grafts were decapitated at the cemento-enamel junction and the selected root was separated longitudinally to entirely expose the pulp chamber using a rotating carbide bur under gentle water (i.e., sterile saline) cooling. Subsequently, all specimens were thoroughly scaled and root planned using curettes to remove all detectable deposits. In addition, any residual pulp tissue and/or root canal filling material was removed and the pulp chamber was widened using a round carbide bur (i.e., sterile saline).

Tooth roots specimens were adapted to match the height and width of the target area and fixed using one to two titanium osteosynthesis screw (1.5 × 9 mm, Medicon). Periosteal-releasing incisions were performed to achieve a tension-free wound closure. At 26 weeks, commercially available titanium implants (Bone Level® Tapered SLActive®, diameter: 4.1 mm, Institut Straumann AG) were inserted in an epicrestal position (Visit 6) without the need for secondary bone grafting procedures. The sutures were removed after 10 ± 4 days (Visit 7—V7). The intraoperative measurements of CW values were accomplished to the nearest 0.25 mm at the most coronal level of the residual buccal bone plate by using a caliper and have been reported recently.

2.5 | Prosthodontic procedure

In all patients, a conventional implant loading (Visit 8—V8) was accomplished at 9 to 20 weeks after V7 (Table 2). All implants were restored with cemented single metal-ceramic crowns and bridges and crown margins being located in an epimucosal position. Intraoral radiographs were taken to ensure the correct position of the respective components and detect residual cement.

2.6 | Clinical measurements

The following clinical measurements were recorded at V8 and after 26 ± 4 weeks (Visit 9—V9) of implant loading (Table 2) using a pressure-calibrated (20–25 g) and color coded plastic periodontal probe (Click-Probe® green, Kerr GmbH): (a) plaque index (PI) (Löe, 1967), (b) bleeding on probing (BOP), evaluated as present if bleeding was evident within 30 s after probing, or absent, if no bleeding was noticed within 30 s after probing, (c) probing depth (PD) measured from the mucosal margin to the bottom of the probeable pocket, (d) mucosal recession (MR) measured from the crown margin to the mucosal margin, and (e) clinical attachment level (CAL) measured from crown margin to the bottom of the probeable pocket. All measurements were recorded at six aspects per implant: mesiovestibular (mb), midvestibular (b), distovestibular (db), mesiooral (mo), midoral (o), and distooral (do) by one calibrated investigator masked to the specific experimental conditions (D.S.).

The presence of peri-implant diseases at each implant site was assessed as follows: peri-implant mucositis: presence of BOP and/or suppuration with or without increased PD (i.e., V8–V9); peri-implantitis: presence of BOP and/or suppuration with increased PD and presence of bone loss (i.e., V8–V9) (Berglundh et al., 2018). No intraoral radiographs were taken, since clinical examinations during follow-up did not suggest the presence of peri-implantitis at any implant site investigated.

2.7 | Postoperative care

Postoperative maintenance care included a supramucosal-/gingival professional implant/tooth cleaning and reinforcement of oral hygiene. Maintenance care was provided according to individual needs at V8 and V9.

2.8 | Statistical analysis

The statistical analysis of the pseudonymised data sets was accomplished using a commercially available software program (IBM SPSS Statistics 24.0, IBM Corp.).

Mean values, standard deviations, medians, 95% confidence intervals (CI), and frequency distributions were calculated for all clinical parameters. The changes (*d*) in mean values from V8 to V9 were examined with the Shapiro–Wilk test. In a next step, within group comparisons of dBOP, dPD, dCAL, and dKT values were accomplished using the Wilcoxon signed-rank test. Subsequently, within group changes of dPD and dCAL values were further analyzed using the paired *t* test. Linear regression analyses were used to depict the relationship between CWg and changes in BOP as well as PD values. The chi-square test was employed to compare the incidence of peri-implant disease between two subgroups. The α error was set at .05.

3 | RESULTS

Mean CW26 values amounted to 11.23 ± 2.42 mm (median: 11.5) with a CWg of 4.73 ± 2.26 mm (median: 5.0).

3.1 | Clinical measurements

At V9, all patients investigated exhibited a good level of plaque control, as indicated by mean PI scores of 0.53 ± 0.55 (Median: 0.17) at respective implant sites.

Mean and median BOP, PD, MR, CAL, and KT values measured at V8 and V9 are summarized in Table 3. At V8, mean BOP scores were 65.38 ± 37.59% and decreased by 19.23 ± 35.32%, thus resulting in a mean BOP value of 46.15 ± 38.01% at V9 ($p = .002$, Shapiro–Wilk test; $p = .078$, Wilcoxon signed-rank test). Mean BOP changes were more pronounced at extraction sites exhibiting a thin buccal bone plate. At V8, mean PD scores were 2.58 ± 0.30 mm and slightly increased by 0.24 ± 0.49 mm, thus resulting in a mean PD value of 2.83 ± 0.39 mm at V9 ($p = .123$, Shapiro–Wilk test; $p = .045$ Wilcoxon signed-rank test; $p = .094$, paired t test). These changes were slightly higher at extraction sites exhibiting a buccal dehiscence-type defect (Tables 4 and 5). All sites investigated did not reveal any noticeable changes in mean MR values at V9. Accordingly, mean CAL changes amounted to 0.24 ± 0.49 mm ($p = .123$, Shapiro–Wilk test; $p = .045$, Wilcoxon signed-rank test; $p = .094$, paired t test), with slightly higher changes noted at extraction sites exhibiting a buccal dehiscence-type defect (Figure 1, Tables 4 and 5). Mean KT values at V8 were 3.23 ± 1.16 mm and mainly changed by 0.80 ± 1.7 mm ($p = .001$, Shapiro–Wilk test; $p = .317$, Wilcoxon signed-rank test) at extraction sites exhibiting a buccal dehiscence-type defect (Tables 4 and 5).

3.2 | Incidence of peri-implant disease

The frequency distribution of peri-implant disease at V9 is summarized in Table 6. According to the given case definitions, the incidence of peri-implant mucositis and peri-implantitis amounted to 76.92% and 0.0%, respectively. The chi-square test pointed to an independency between both subgroups and the incidence of peri-implant disease ($p = .118$) (Table 6).

3.3 | Regression analysis

At V6, mean CWg values amounted to 4.89 ± 2.29 mm (median: 5.00; 95% CI: 3.56; 6.21) (Schwarz et al., 2019).

The linear regression analysis failed to reveal a significant correlation between CWg and changes in BOP (Coef: 0.321, $R^2 = .103$, $p = .285$) and PD values (Coef: 0.167, $R^2 = .028$, $p = .585$, respectively (Figure 2a,b).

4 | DISCUSSION

The present study aimed at investigating the short-term clinical outcomes of lateral augmentation of deficient extraction sockets and two-stage implant placement using TR. After a follow-up period of 44 weeks (i.e., at 26 ± 4 weeks after loading), all patients investigated revealed non-significant changes in mean BOP (−19.23 ± 35.32%), PD (0.24 ± 0.49 mm), MR (0.0 ± 0.0 mm), and CAL (0.24 ± 0.49 mm) values when compared with V8. In this context, it must be emphasized that the present observational study had a proof-of-principle character and may therefore not have the statistical power to rule out significant within group changes for the presented clinical outcomes. Moreover, it must be emphasized that the relatively high BOP scores noted at V8 may mainly be attributed to a traumatic tissue injury caused by the crown/bridge insertion at respective implant sites. Accordingly, the BOP changes at V9 reflect a healing of the peri-implant soft tissue following completion of the implant supported restorations.

The remaining mean BOP scores at 44 weeks are basically within the range of the short-term data on peri-implant health or disease noted at native (non-augmented) implant sites (Schwarz et al., 2017). In particular, in a cross-sectional analysis of 238 patients exhibiting a total of 512 two-piece implants, the diagnosis peri-implant

TABLE 3 (a) Clinical parameters measured at V8 (n = 13 patients). (b) Clinical parameters measured at V9 (n = 13 patients)

	BOP	PD	MR	CAL	KT
(a)					
Mean	65.38	2.58	0.00	2.58	3.23
SD	37.59	0.30	0.00	0.30	1.16
Median	67.00	2.67	0.00	2.67	3.00
95% CI	42.6; 88.1	2.40; 2.76	0.00; 0.00	2.40; 2.76	2.52; 3.93
(b)					
Mean	46.15	2.83	0.00	2.83	3.53
SD	38.01	0.39	0.00	0.39	1.33
Median	33.00	2.92	0.00	2.92	3.00
95% CI	23.18; 69.13	2.59; 3.07	0.00; 0.00	2.59; 3.07	2.73; 4.34

TABLE 4 Changes (*d*) in clinical parameters between V8 and V9 (*n* = 13 patients)

TR	dBOP	dPD	dMR	dCAL	dKT
Mean	−19.23 ± 35.32	0.24 ± 0.49	0.0 ± 0.0	0.24 ± 0.49	0.30 ± 1.1
Median	0.0	0.17	0.0	0.17	0.0
95% CI	−40.57; 2.11	−0.04; 0.54	0.0; 0.0	−0.04; 0.54	−0.36; 0.97
Cohen's *d*	−0.54	0.50	-	0.50	0.27
p value	.078[a]	.094[b]	-	.094[b]	.317[a]

Note: Within group comparison V8–V9: [a]Wilcoxon signed-rank test; [b]Paired *t* test.

TABLE 5 (a) Patients exhibiting extraction sockets with a thin buccal bone plate (<0.5 mm) (*n* = 8). (b) Patients exhibiting extraction sockets with a buccal dehiscence-type defect (*n* = 5)

(a)					
TR	**dBOP**	**dPD**	**dMR**	**ΔdCAL**	**dKT**
Mean	−27.13 ± 39.82	0.15 ± 0.56	0.0 ± 0.0	0.15 ± 0.56	0. 0 ± 0.0
Median	0.0	0.17	0.0	0.17	0.0
95% CI	−60.42; 6.17	−0.31; 0.63	0.0; 0.0	−0.31; 0.63	0.0; 0.0
(b)					
TR	**dBOP**	**dPD**	**dMR**	**dCAL**	**dKT**
Mean	−6.60 ± 25.35	0.39 ± 0.34	0.0 ± 0.0	0.39 ± 0.34	0.80 ± 1.7
Median	0.0	0.50	0.0	0.50	0.0
95% CI	−38.08; 24.88	−0.03; 0.83	0.0; 0.0	−0.03; 0.83	−1.42; 3.02

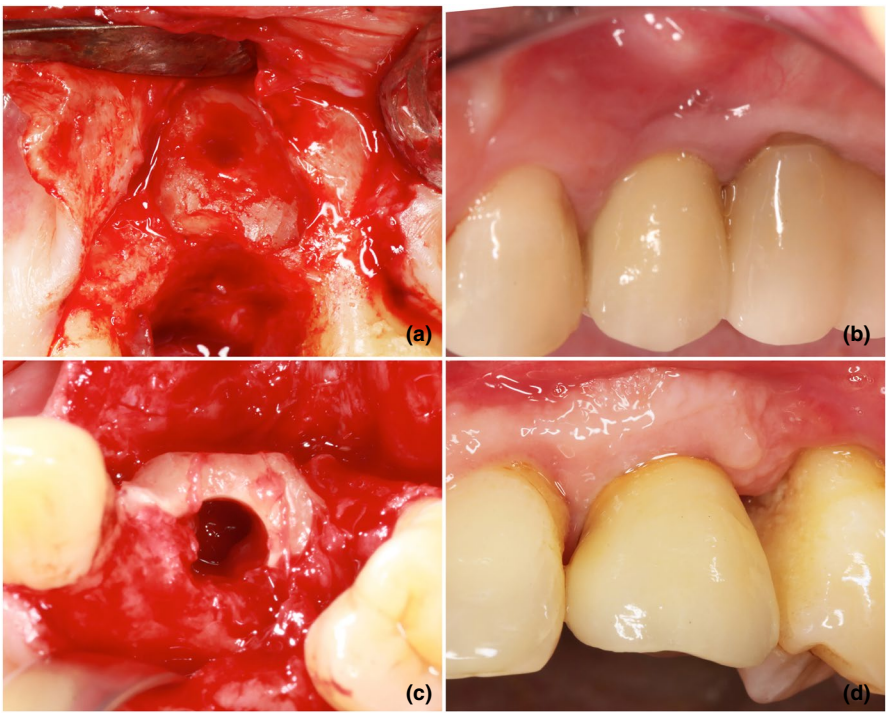

FIGURE 1 Representative clinical outcomes at V9. (a) Situation at re-entry in the region of former tooth 25 where TR had been used for the augmentation of a thin buccal bone plate (Visit 6). (b) Healthy peri-implant soft tissue conditions as indicated by the absence of BOP. (c) Situation following implant bed preparation in the region of former tooth 23, where TR had been used for the augmentation of a buccal dehiscence-type defect (Visit 6). (d) Clinical situation immediately following gentle probing pointing to healthy and stable peri-implant soft tissues

mucositis (case definition: BOP on at least one aspect of the implant but no changes in the radiographic bone level) was commonly noted in all implant age groups investigated. At the implant level, its frequency amounted to *n* = 25 at 1–12 months of follow-up, *n* = 157 at 12–48 months and *n* = 32 at >48 months, respectively (Schwarz et al., 2017). In contrast, a meta-analysis (*n* = 10 studies) of short-/mid-term (1–3 years) and long-term (>3 years) data on the effects of various lateral ridge augmentation procedures on peri-implant

health or disease did not reveal any major changes in BOP scores over time (i.e., follow-up of 1–10 years). The calculated weighted mean differences amounted to −10.02% (95% CI: −22.23; 2.21) and failed to reach statistical significance (Sanz-Sanchez et al., 2018). Similar findings with respect to BOP changes were also observed when different timings (i.e., simultaneous or staged) and surgical procedures (i.e., different types of barrier membranes, growth factors, chin blocks with or without resorbable membranes) were compared ($n = 6$; WMD = −3.36; 95% CI [−12.49; 5.77]; $p = .471$). These procedures were also associated with stable PD scores ($n = 6$; WMD = −0.051; 95% CI 0.0; 0.0]; $p = .726$) and marginal bone levels ($n = 6$; WMD = 0.062; 95% CI 0.0; 0.527]; $p = .284$) (Sanz-Sanchez et al., 2018), thus corroborating the findings of the present study.

TABLE 6 Crosstabulation of subgroup and incidence of peri-implant disease at V9

	Diagnosis		
	0	1	Total
Subgroup			
Thin bone			
Count	3	5	8
% within subgroup	37.5%	62.5%	100.0%
Dehiscence-type defect			
Count	0	5	5
% within Subgroup	0.0%	100.0%	100.0%
Total			
Count	3	10	13
% within Subgroup	23.1%	76.9%	100.0%

Note: Diagnosis: 0 = healthy; 1 = peri-implant mucositis; $p = .118$, chi-square test.

At the time being, this is the first clinical study which aimed at investigating the application of TR for a lateral augmentation of deficient extraction sockets. However, a recent prospective case series (four patients) reported on the clinical performance of TR grafts (derived from impacted teeth) for lateral alveolar ridge augmentation and staged implant placement (Pohl et al., 2017). The clinical follow-up at 2 years revealed mean PD scores of 1.7 mm (range: 0–3.5 mm) in the absence of BOP (Pohl et al., 2017). This was also supported by the outcomes of an initial human case report, pointing to healthy and stable (PD values of 3–4 mm) peri-implant tissue conditions at 8 months following lateral ridge augmentation using

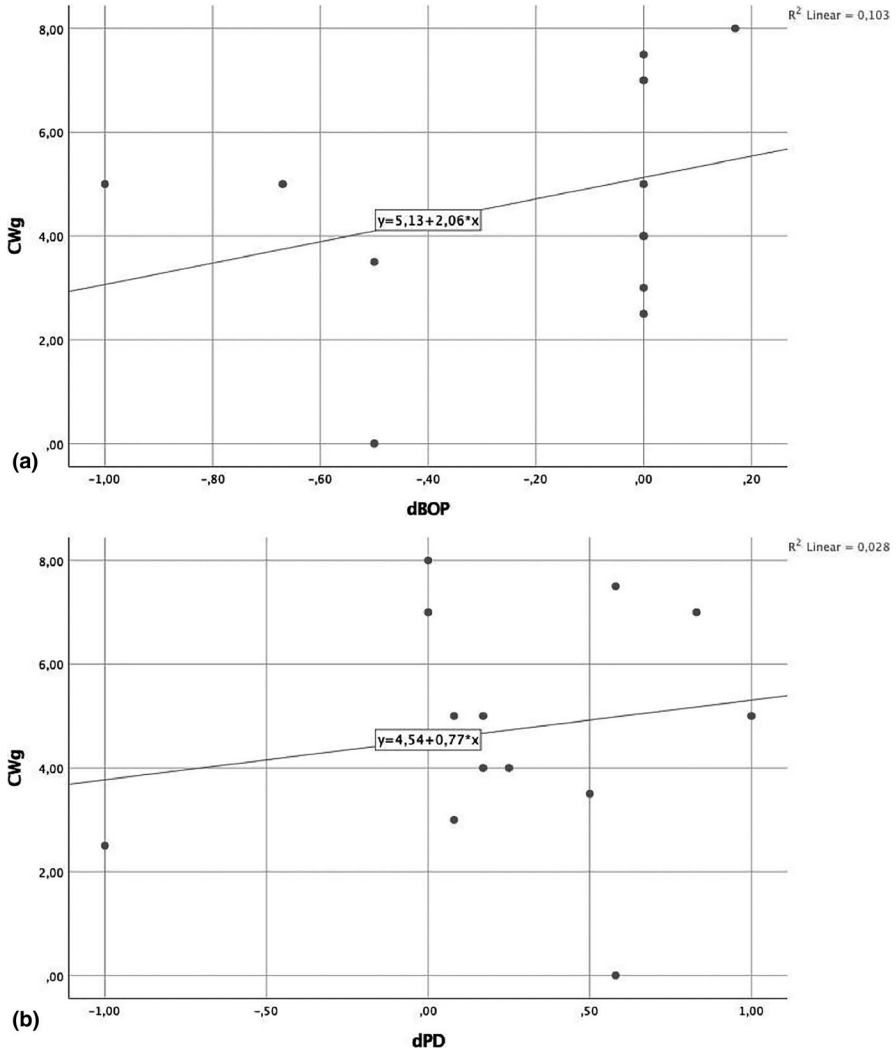

FIGURE 2 Linear regression plots to depict the relationship between CWg and dBOP/dPD values. (a) dBOP. (b) dPD

TR and staged implant placement (Schwarz, Schmucker, & Becker, 2016).

When further analyzing the present regression analysis, it was also noted that the initial gain in ridge width was not significantly correlated with changes in BOP and PD values. While this observation may support recent findings of a less pronounced resorption of TR when compared with AB grafts (Schwarz, Hazar, Becker, Sader, & Becker, 2018), it remains unclear to what extent graft remodeling will affect both TR groups and subsequently clinical outcomes in the mid- and long-term.

A major limitation of the present clinical analysis was the impossibility to further assess the biological integration of the inserted implants at TR grafted sites. However, previous preclinical animal studies provide histological evidence that a true osseointegration was established by the interposition of woven bone between residual TR fragments and the implant surface (Schwarz, Golubovic, Becker, & Mihatovic, 2016). The resulting removal torque values were comparable to those values noted at titanium implants that were placed following lateral ridge augmentation using autogenous bone blocks (Becker et al., 2017).

In conclusion and within its limitations, the present clinical study revealed that the surgical procedure was associated with stable peri-implant tissues on the short-term.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interests related to this study.

AUTHOR CONTRIBUTIONS

Puria Parvini: Conceptualization (equal); Data curation (equal); Formal analysis (equal); Investigation (equal); Validation (equal); Writing-review & editing (equal). **Didem Sahin:** Data curation (lead); Investigation (equal); Writing-review & editing (equal). **Kathrin Becker:** Formal analysis (lead); Methodology (equal); Software (equal); Supervision (equal); Visualization (equal); Writing-review & editing (equal). **Robert Sader:** Conceptualization (equal); Formal analysis (equal); Project administration (supporting); Writing-review & editing (equal). **Juergen Becker:** Resources (lead); Supervision (equal); Writing-review & editing (equal). **Frank Schwarz:** Conceptualization (lead); Data curation (equal); Formal analysis (equal); Funding acquisition (lead); Investigation (lead); Methodology (equal); Project administration (lead); Validation (equal); Writing-original draft (equal).

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SUPPORTING INFORMATION

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

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