Submerged vs Nonsubmerged Reconstructive Approach for Surgical Treatment of Peri-implantitis: Reanalysis of Two Prospective Clinical Studies

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Purpose: To complete a reanalysis study of two similarly designed prospective controlled studies exploring prognostic factors associated with the surgical outcomes of reconstructive treatment of peri-implantitis. ***Materials and Methods:*** Individual patient data of both studies were gathered. The initial study employed a submerged healing approach via primary wound closure with implant suprastructure removal and complete coverage of grafted sites. The second study employed a nonsubmerged healing protocol in which healing abutments were kept in place and the implants were not fully submerged. Both studies measured all prognostic factors at similar time points throughout 1 year and included clinical defect fill (DF) and radiographic defect fill (RDF), reduction of pocket depth (PDR), and bleeding on probing (BoP). Multilevel regression was used for statistical assessment of outcomes relative to the impact of site, local, surgical, and patient-related variables. ***Results:*** Overall, 59 implants (30 submerged and 29 nonsubmerged) were treated. Statistically significant higher DF (on average 0.9 mm higher), RDF (1.7 mm), and PDR (1.3 mm) were observed when a submerged reconstructive approach was performed, whereas BoP reduction was similar. After controlling for treatment (submerged/nonsubmerged), there were no other significant associations with patient-related (age, sex, smoking, prior periodontitis etc), or implant-related (previous prosthesis type, arch, keratinized tissue width [KTW], etc) factors. ***Conclusions:*** Within the study's limitations, we conclude that a submerged reconstructive approach for surgical management of peri-implantitis leads to significantly enhanced clinical and radiographic outcomes when compared to a nonsubmerged approach. *Int J Oral Maxillofac Implants 2024;39:526–536. doi: 10.11607/jomi.10560*

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Dental implant therapy has been a well-established rehabilitation method to treat edentulism for decades that has rendered satisfactory outcomes for patients and clinicians.[1–3] The exponential growth in the use and popularity of implants also requires consideration of their complications and diseases, as well as proper methods for their management when encountered.[3–7] Peri-implantitis has been one of the most challenging complications related to dental implants.[1,8,9] It has been shown to have a microbial etiology, occurring via an inflammatory response, that results in irreversible loss of the peri-implant supporting alveolar bone.[2,8–10] Studies have shown prevalence rates of 18.5% and 12.8% at the patient and implant level, respectively.[2,5,11,12]

The resolution of peri-implantitis is dependent upon the eradication of the microbial biofilm (as the causative factor) and cessation of the active peri-implant inflammation, avoiding further loss and breakdown of peri-implant supporting structures.[13,14] The current evidence suggests that nonsurgical treatment of peri-implantitis yields limited and unpredictable outcomes. Therefore, in cases of moderate to advanced peri-implantitis, surgical therapy may be effective[15–19] due to the crucial visibility and access that is provided. This allows for enhanced debridement of the bony defect and decontamination of the implant surface.[20,21] Nonetheless, recent studies have shown that surgical debridement therapy alone fails to yield satisfactory results and may lead to disease recurrence, jeopardizing the medium- or long-term outcomes.[22–24] Indeed, it is important to note that even with successful resolution of the peri-implant disease through a surgical therapy, the disease is irreversible in nature; without attempts for reconstruction of the lost peri-implant supporting

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tissues, the implant site remains devoid of its original supporting structures.[21,25]

Therefore, a combination of conventional surgical therapies with guided bone regenerative techniques (with the use of various grafting materials and barrier membranes) have gained popularity and have been applied when dealing with peri-implantitis.[18,26–30] Based on the main method of approach, these can be divided into either a submerged or a nonsubmerged healing approach. A submerged protocol involves the removal of implant suprastructures (ie, prosthesis) to obtain primary wound closure for carrying out submerged healing of the grafted defect. The nonsubmerged approach, on the other hand, implies a healing where the prosthetic suprastructure remains in position, and therefore the implant is not fully submerged.[10,31,32] Despite the fact that there are some reports in the literature discussing the outcomes of both techniques individually, we found that no human clinical study has yet been performed that compares the two approaches for the management of peri-implantitis and assesses the amount of bone augmentation as a result of treatment. Therefore, the aim of the present study was to compare the submerged and nonsubmerged reconstructive protocols for surgical treatment of peri-implantitis bony defects and explore the factors relevant to the outcomes of disease resolution and bone augmentation.

MATERIALS AND METHODS

Study Design and Characteristics

The current study was designed as a reanalysis of two prospective controlled clinical studies that were conducted in the same center for the surgical reconstructive treatment of peri-implantitis.[10] In one study,[10] patients received surgical reconstructive treatment for peri-implantitis bony defects with a uniform submerged healing protocol. In the other,[32] all participants received a nonsubmerged reconstructive approach for peri-implantitis. Complete details pertaining to both studies can be found in their respective publications.[10,32] Both studies were conducted in a close time frame (from June 2017 to December 2020) in the same clinic (author SCW) , and all subjects were recruited from the same patient pool, with similar inclusion criteria. The inclusion criteria comprised systemically healthy adults (or with only a well-controlled mild to moderate disease) requiring treatment for at least one bone-level titanium dental implant diagnosed with peri-implantitis[1,9] that presented with a vertical bony defect (of at least 3 mm) and surrounding bony walls (ie, crater-like defects) without mobility. The exclusion criteria were as follows: Patients with implants placed completely outside the bony housing or presenting with a complete horizontal pattern of bone loss; patients who smoked more than 10 cigarettes daily; patients who received recent (within 2 months) antibiotic therapy; patients who were pregnant or taking medications that could alter bone metabolism[33]; and patients with untreated periodontal disease or inadequate oral hygiene (O'Leary plaque index > 50%).

All patients were treated by the same experienced operator (SCW) and were followed for an entire year time postoperatively with similar intermediate time points (Fig 1). Aside from the method for the reconstructive approach, all other study components pertaining to the treatment protocols and outcomes were identical.

This reanalysis study was also in full accordance with the Declaration of Helsinki of 1965, as revisited in Tokyo in 2013, and was approved by the Institutional Review Board and the local ethical committee (Stomatological Hospital of Xiamen Medical College, #18950051616). All patients provided their written informed consent prior to all treatments, and the current manuscript was prepared following the items presented in the STROBE statement (www.strobe-statement.org).

Treatment Protocol

Peri-implant defect debridement and implant surface detoxification

After profound local anesthesia, a full-thickness flap was elevated on the buccal and lingual/palatal aspects of the implants to gain access to the peri-implant defect. Vertical releasing incisions were also placed as needed at a distance of at least one tooth or implant away from the surgical site.

Debridement of the peri-implant defect was initiated with mechanical hand instrumentation using periodontal curettes (Gracey curettes, Hu-Friedy) to achieve thorough degranulation.

Next, implant surface detoxification was performed using a combination of mechanical and chemical remedies, including implantoplasty on the exposed threads using rotary instruments (Meisinger, Hager & Meisinger) under copious irrigation and an air-abrasive device with glycine powders (AirFlow, EMS); these were followed by chemical decontamination using a locally administered antimicrobial agent for 5 minutes (2.5 mL of 250 mg tetracycline).

Submerged versus nonsubmerged reconstructive healing approach

After thorough defect degranulation and implant surface debridement, the augmentation phase was initiated by placing multiple perforations on the cortical aspect of the bone to be augmented using a ¼ round bur.

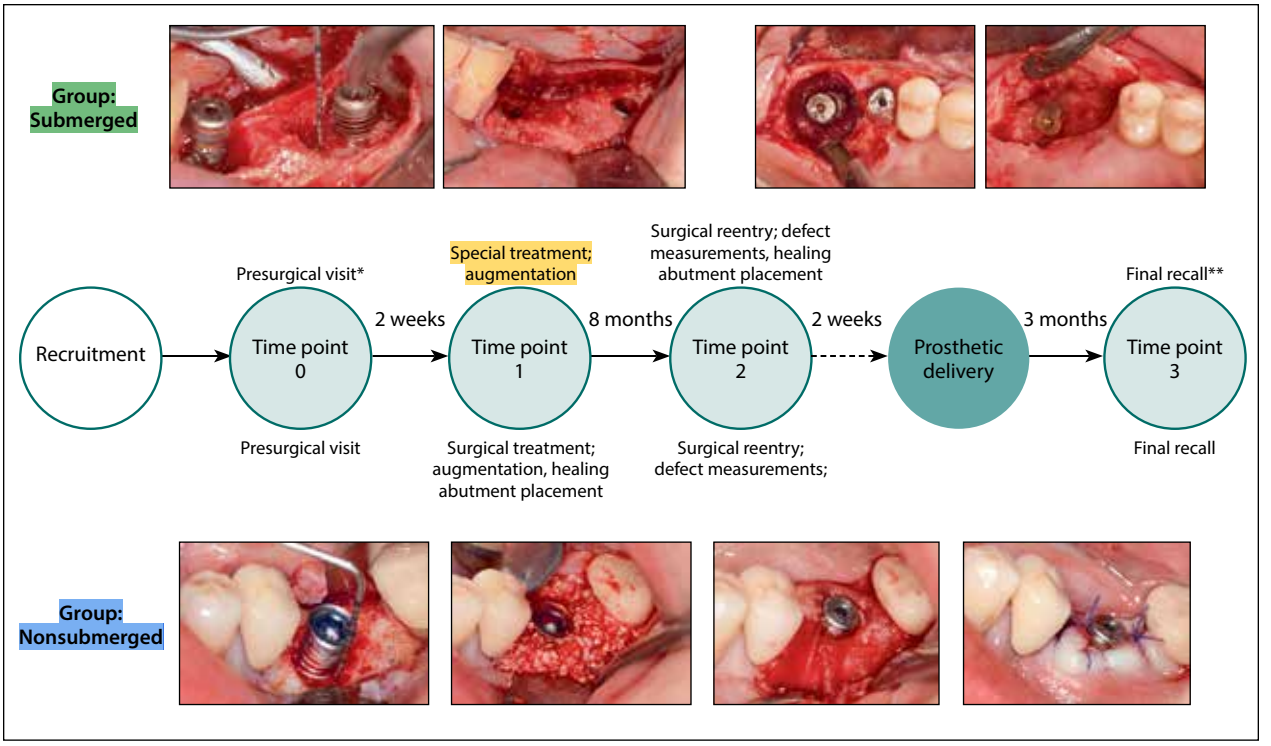

Fig 1 Timeline of included studies at a glance. *Presurgical visit included crown removal and nonsurgical therapy phase. **In the final recall visit, BoP and PDR were measured.

In the 22 patients who were part of the submerged healing approach,[10] all prosthetic suprastructures (implant crowns and healing abutments) had been removed 4 to 6 weeks prior to the surgical procedure and replaced with cover screws. A composite bone graft of a combination of approximately 60% freeze-dried bone allograft (Maxgraf, Botiss), 20% mineralized bovine bone (Cerabone, Botiss), and 20% autogenous bone (collected using a bone scraper from the adjacent ramus or maxillary tuberosity) was utilized to completely fill the peri-implant defect; next, a nonabsorbable dense polytetrafluoroethylene membrane (dPTFE) (Osteogenics Biomedical) was trimmed and stabilized using fixation screws (Master Pins, Osteogenics Biomedical) to completely submerge the implant and the augmented areas. Care was taken to ensure that the membrane was resting on bone and not in contact with adjacent dentition.

Periosteal releasing incisions were placed to allow for passive flap advancement. Tension-free primary wound closure was then achieved to fully cover the augmented sites and the treated implants by placing monofilament nonresorbable horizontal mattress and single interrupted sutures (4/0, Cytoplast PTFE suture, Osteogenics Biomedical).

For the 24 patients who were part of the second study[32] with a nonsubmerged healing approach, the implant prosthetic components were removed at the time of the surgical intervention and replaced with appropriate healing abutments. This was done to enhance surgical access and aid in mechanical and chemical peri-implant defect and implant surface decontamination. The same composite bone graft as the submerged study was then utilized to fill the peri-implant defect; subsequently, a collagen membrane (Jason Pericardium membrane, Botiss) was trimmed and adapted to cover the grafted sites with a small perforation on its crestal portion (on the area corresponding to the implant) to allow for passing of the healing abutment. Periosteal releasing incisions were placed to allow for tension-free closure around the replaced healing abutment, to completely cover the grafted peri-implant regions, using single interrupted and horizontal mattress sutures (Vicryl, Ethicon, Johnson & Johnson); this made a seal around the healing abutments without fully submerging the implants.

Postoperative care and follow-up appointments

Detailed oral and written instructions were provided to all patients to similarly include oral hygiene care and maintenance of the treated sites as well as prescriptions for oral systemic antibiotics. The antibiotic regimen was as follows: 500 mg of amoxicillin three times a day for 10 days or, if allergic to penicillin, 250 mg of azithromycin (six tablets total) starting with two tablets on the first day and then taken once daily until gone. Ibuprofen

600 mg was also prescribed to be taken as needed. Patients were also recommended to rinse twice daily with a 0.12% chlorhexidine mouth rinse for the first 2 weeks.

All patients were seen at 2 weeks for suture removal, followed by postoperative recall appointments at 6 weeks, 4 months, 6 months, and 8 months. At the 8-month mark, a reentry procedure for all sites was performed.

Reentry visit after 8 months of healing

Following 8 months of undisturbed healing, a reentry procedure was performed for all implants to gain access to the treated sites and evaluate the augmented regions. It was planned that in case of an unsuccessful reconstructive procedure or residual peri-implant defect, further bone augmentation would be performed as necessary at this visit.

After flap elevation, the augmented sites were reassessed, and measurements were taken relative to the implants. Single interrupted sutures were then placed for flap readaptation to be removed after 2 weeks.

Following flap elevation in sites that had received a submerged healing approach, nonabsorbable membranes and titanium screws were also removed, followed by the replacement of the implant cover screws with appropriate healing abutments.

During this time, new prostheses were fabricated and planned to be delivered to all patients who agreed to have a new crown replacement. For patients who did not agree to new prostheses, the contours of the implant crowns were adjusted to facilitate at-home oral hygiene care and professional supportive therapy.

Final study visit

Approximately 3 months after the replacement of implant crowns and prosthetic components, all patients returned for a final check of the healing outcomes and to obtain clinical measurements (as performed at the surgical visit prior to initiation of treatment). All patients were subsequently enrolled in a 3-month supportive maintenance care and recall program to be adjusted individually as needed.

Original Study Outcomes

The primary endpoint of both original studies was direct clinical measurements of bone gain as a result of the surgical reconstructive procedure. This was assessed as changes in direct linear measurements of peri-implant bone after the 8 months of undisturbed healing.

The measurements were obtained at the time of surgical treatment (following defect degranulation) and at the 8-month reentry visit (after flap reflection) using a periodontal probe (PCP-UNC 15, Hu-Friedy) at four sites of the implant (buccal, lingual/palatal, mesial, and distal relative to the implant platform); the measurements were performed by the same calibrated investigator (SCW) and termed clinical vertical defect fill (DF):

$$DF = \text{Clinical vertical defect depth at baseline} - \text{Clinical vertical defect depth) at 8 months}$$

The average change at the four implant sites constituted the implant score, reflecting the mean clinical bone gain per treated implant.

The examiner calibration was performed using 10 randomly selected cases and to achieve an intraexaminer measurement reliability of 85%.

Secondary outcomes of the original studies similarly included linear changes in radiographic bone levels and clinical measurements of peri-implant probing pocket depth (PD) as well as assessment of BoP.

Radiographic bone level changes were assessed by comparing two CBCT scans, obtained prior to the surgical treatment and 8 months later prior to surgical reentry, to evaluate radiographic changes in peri-implant bone levels at the same four implant regions (buccal, lingual/palatal, mesial, and distal). This was referenced as the *radiographic defect fill* (RDF) and was computed as follows:

$$RDF = \text{Radiographic vertical defect depth at baseline} - \text{Radiographic vertical defect depth at 8 months}$$

Similar to the outcome of DF, the changes at the four peri-implant sites were averaged to present the implant score as it relates to the outcome of RDF.

Further information on the exact process of the radiographic examination and measurements can also be found in both published reports.[10,32]

Changes in PD from baseline (prior to any intervention or crown removal) until the final study visit (3 months after replacement of prostheses, corresponding to approximately 12 months after the surgical treatments) were also measured to obtain PD reduction (PDR) at six implant sites. These sites were as follows: distobuccal, buccal, mesiobuccal, mesiolingual, lingual/palatal, and distolingual. BoP was assessed dichotomously (yes/no) within 30 seconds of gentle probing at each implant site; nonetheless, an implant was marked as BoP-positive even if one site out of six presented with BoP at any time. Similar to the outcomes of DF and RDF, implant scores were calculated for PD and BoP to convey changes after treatments per each implant as follows:

$$PDR = PD \text{ at baseline} - PD \text{ at 12 months}$$

$$BoP \text{ reduction} = BoP \text{ at baseline (\%)} - BoP \text{ at 12 months (\%)}$$

Data Analysis and the Current Reanalysis Study Aims

The primary goal of this reanalysis study was to build upon a relatively large and homogeneous patient cohort who had undergone surgical reconstructive treatment for peri-implantitis in order to explore variables associated with direct clinical measurements of bone gain (vertical defect fill, DF), specifically to investigate the effect of local-/site-, systemic-, and surgical-related aspects on the main outcome of DF.

The individual data from both studies were pooled into the same spreadsheet to include patient demographics such as age, sex, smoking habits, past history of periodontal diseases, and more. Local- and site-related factors were as follows: The type of the original prosthesis (cement- vs screw-retained); the location of the implant in the arch (maxilla vs mandible); the area where the implant is located(molar vs premolar site); and the baseline characteristics such as severity of initial PD, keratinized tissue width (KTW), and defect depth. Finally, the surgical factor was the type of reconstructive approach (submerged vs nonsubmerged).

Data was initially analyzed descriptively to report the parameters mentioned above by using frequencies and percentages for categorical variables and means with SD for continuous outcomes.

A mixed-linear regression modeling approach was utilized for statistical assessment of changes in the continuous outcomes of DF (mm) as well as the secondary outcomes of RDF (mm), and PDR (mm). Mixed-logistic regression models were used for analysis of BoP (yes/no). The models accounted for repeated measures (ie, patients who had more than one implant treated, etc) by including random effects for implants within patients and fixed effects for the main variables of interest and time. A stepwise regression approach (using likelihood ratio tests) was employed to first univariately introduce independent variables for their association with the observed outcomes. Multivariate models were then produced to identify prognostic factors for the outcomes. Interactions were also tested between different variables and outcomes to explore their influence (eg, interaction between baseline KTW and the reconstructive approach).

Model coefficients were reported with their corresponding standard errors (SE) and 95% confidence intervals (CIs). A *P* value of .05 was set for statistical significance.

All current data analysis was performed by an investigator who was not involved in any of the surgical procedures or clinical assessments and remained blinded to the primary patient data (HS).

RESULTS

Study Population

Table 1 presents complete demographic information of the entire cohort as well as for each treatment group (submerged and nonsubmerged).

Overall, 46 patients (17 females and 29 males; mean age 56 ± 10.88 years) with a total of 59 dental implants diagnosed with peri-implantitis were treated as part of both studies. Of these implants, 30 received a submerged healing approach and 29 underwent a nonsubmerged healing approach.

All dental implants were bone level and in function for at least 3 years prior to the diagnosis of peri-implantitis. The implants were all located in the posterior region, 18 in the premolar zone and 41 in the molar area. A total of 21 were in the maxillary arch, and 38 were in the mandibular arch. In addition, 12 of the 46 patients had adjacent implants with peri-implantitis that both received treatment as part of the study. The remaining 34 patients only had a single implant affected with peri-implantitis.

Twelve patients reported cigarette smoking (less than 10 cigarettes per day), and most patients had a history of periodontal disease.

Descriptive Assessment of Outcome Changes with Surgical Reconstructive Therapy for Peri-implantitis

Table 2 describes all clinical and radiographic assessments at their respective time points as well as their changes for both studies.

Regardless of the method of reconstructive treatment in both studies , the measurements for PDR taken at the final visit were reduced, on average 2.93 ± 0.25 mm in the submerged group and 1.51 ± 1.17 mm in the nonsubmerged group. DF was also observed at all sites in both groups and was recorded as 3.22 ± 0.41 mm in the submerged group and 2.33 ± 1.88 mm in the nonsubmerged group. RDF was achieved in both groups, with 3.47 ± 0.41 mm in the submerged group and 1.63 ± 1.7 mm in the nonsubmerged group. Additionally, both treatments provided similar rates of BoP reduction, starting at 100% at baseline and dropping down to 36.6% and 34.5% in the submerged and nonsubmerged groups, respectively.

Identifying Prognostic Factors for Surgical Reconstructive Treatment of Peri-implantitis

Clinical vertical defect fill (DF)

Table 3 depicts the results of the univariate and multivariate analyses evaluating the impact of different factors on the DF.

In the univariate analysis, the arch (ie, the maxilla) and the reconstructive method (ie, the submerged

Table 1 Descriptive Data of Treated Patients at Baseline

		Value (%)		
		Total	Submerged healing approach	Nonsubmerged healing approach
Patients (N = 46)	**Age (mean ± SD)**	56 ± 10.88 years	56.8 ± 13.14 years	54.6 ± 10.77 years
	Sex			
	Female	17 (37%)	10 (45%)	7 (29%)
	Male	29 (63%)	12 (55%)	17 (71%)
	Previous history of periodontal disease			
	Yes	40 (87%)	18 (81%)	22 (92%)
	No	6 (13%)	4 (19%)	2 (8%)
	Smoker*			
	Yes	12 (26%)	7 (32%)	5 (21%)
	No	34 (74%)	15 (68%)	19 (79%)
Implants (N = 59)	**Arch**			
	Maxilla	21 (35.6%)	8 (22%)	13 (45%)
	Mandible	38 (64.4%)	22 (73%)	16 (55%)
	Implant site			
	Premolar	18 (30.5%)	8 (22%)	10 (35%)
	Molar	41 (64.4%)	22 (73%)	19 (65%)
	Previous prosthesis type			
	Cement-retained	34 (57.6%)	15 (50%)	19 (65%)
	Screw-retained	25 (42.4%)	15 (50%)	10 (35%)
	Treatment approach			
	Submerged	30 (50.8%)	30 (100%)	—
	Nonsubmerged	29 (49.2%)	—	29 (100%)
	KTW (mean ± SD)	—	0.76 ± 0.85 mm	1.93 ± 0.75 mm

*Refers to smoking < 10 cigarettes per day. Smokers who smoked > 10 cigarettes per day were excluded from both studies.

Table 2 Comparison of Mean Changes in the Outcome Variables Between the Submerged and Nonsubmerged Treatment Groups

		Time point			
Outcome*	Treatment group (healing approach)	1 (Baseline)	2 (8 months)	3 (12 months)	Changes†
PD (mm)	Submerged	5.81 ± 1.48	—	2.91 ± 1.11	2.93 ± 0.25
	Nonsubmerged	4.73 ± 1.15	—	3.22 ± 1	1.51 ± 1.17
DF (mm)	Submerged	3.36 ± 1.74	0.13 ± 1.69	—	3.22 ± 0.41
	Nonsubmerged	5.97 ± 1.46	3.63 ± 1.78	—	2.33 ± 1.88
RDF (mm)	Submerged	3.79 ± 1.66	0.31 ± 1.75	—	3.47 ± 0.41
	Nonsubmerged	5.23 ± 1.32	3.59 ± 1.81	—	1.63 ± 1.7
BoP	Submerged	100%	—	36.6%	63.3%
	Nonsubmerged	100%	—	34.5%	65.5%

*Note that the mean of each variable at each time point is measured as the average number of all measured peri-implant sites.
†Note that the amount of change of each variable is measured by subtracting the mean value of initial time point from secondary time point.

approach) were significantly associated with improved DF outcomes. Nonetheless, in the multivariate assessment, the variable of arch dropped out, and the method of reconstructive approach (submerged) was the only factor that maintained its significance in the model. This indicates a statistically significant higher DF in implants that received the submerged healing approach regardless of all other observed site and patient factors.

Table 3 Univariate and Multivariate Analyses for the Outcome of DF

	Univariate analysis					Multivariate analysis				
			95% CI					95% CI		
Variable	Estimate	SE	Lower	Upper	*P* value	Estimate	SE	Lower	Upper	*P* value
Age	0.005	0.019	−0.034	0.045	.778	—	—	—	—	—
Sex										
Female	0.208	0.459	−0.711	1.129	.651	—	—	—	—	—
Smoking*										
No	−0.364	0.464	−1.294	0.566	.437	—	—	—	—	—
Past history of periodontitis										
Yes	−0.072	0.617	−1.308	1.163	.907	—	—	—	—	—
Arch										
Maxilla	−0.869	0.434	−1.738	0.001	.05	−0.697	0.429	−1.558	0.162	.110
Site										
Premolar	−0.313	0.465	−1.245	0.618	.503	—	—	—	—	—
Previous restoration type										
Cemented	−0.523	0.429	−1.384	0.336	.228	—	—	—	—	—
KTW	−0.234	0.216	−0.667	0.198	.283	—	—	—	—	—
Treatment										
Submerged	0.992	0.409	0.171	1.812	.019	0.865	0.411	0.041	1.689	.04

*Refers to smoking < 10 cigarettes per day. Smokers who smoked > 10 cigarettes per day were excluded from both studies.

Table 4 Univariate and Multivariate Analyses for the Outcome of RDF

	Univariate analysis					Multivariate analysis				
			95% CI					95% CI		
Variable	Estimate	SE	Lower	Upper	*P* value	Estimate	SE	Lower	Upper	*P* value
Age	0.009	0.020	−0.030	0.049	.641	—	—	—	—	—
Sex										
Female	0.073	0.467	−0.863	1.010	.875	—	—	—	—	—
Smoking*										
No	−0.503	0.470	−1.444	0.438	.289	—	—	—	—	—
Past history of periodontitis										
Yes	−0.393	0.625	−0.881	1.667	.539	—	—	—	—	—
Arch										
Maxilla	−0.946	0.439	−1.825	−0.066	.035	−0.602	0.380	−1.365	0.160	.119
Site										
Premolar	−0.340	0.472	−1.286	0.606	.475	—	—	—	—	—
Previous restoration type										
Cemented	−0.249	0.441	−1.132	0.634	.575	—	—	—	—	—
KTW	−0.501	0.211	−0.925	−0.076	.02	.044	0.228	−0.412	0.502	.845
Treatment										
Submerged	1.844	0.362	1.118	2.570	<.001	1.735	0.364	1.004	2.465	< .001

*Refers to smoking <10 cigarettes per day. Smokers who smoked >10 cigarettes per day were excluded from both studies.

Radiographic vertical defect fill (RDF)

Table 4 presents the results of the regression analyses for the outcome of RDF. The univariate analysis showed a significant association between arch (maxilla), baseline KTW, and treatment approach (submerged) with the amount of RDF. However, the multivariate regression revealed that only the submerged method of healing was significantly associated with RDF, with an estimated effect size of 1.73 (95% CI [0.36, 1.04], $P < .001$).

Table 5 Univariate and Multivariate Analyses for the Outcome of PDR

	Univariate analysis					Multivariate analysis				
			95% CI					95% CI		
	Estimate	SE	Lower	Upper	*P* value	Estimate	SE	Lower	Upper	*P* value
Age	0.001	0.015	−0.029	0.032	.92	—	—	—	—	—
Sex										
Female	0.352	0.357	−0.363	1.067	.328	—	—	—	—	—
Smoking*										
No	−0.413	0.361	−1.137	0.310	.257	—	—	—	—	—
Past history of periodontitis										
Yes	−0.056	0.483	−1.024	0.910	.907	—	—	—	—	—
Arch										
Maxilla	−0.418	0.347	−1.113	0.277	.233	—	—	—	—	—
Site										
Premolar	−0.340	0.472	−1.286	0.606	.475	—	—	—	—	—
Previous restoration type										
Cemented	−0.083	0.340	−0.765	0.598	.806	—	—	—	—	—
KTW	−0.623	0.149	−0.923	−0.324	< .001	−0.317	0.173	−0.665	0.031	.073
Treatment										
Submerged	1.390	0.281	0.826	1.955	< .001	1.021	0.342	0.335	1.107	.004

*Refers to smoking < 10 cigarettes per day. Smokers who smoked > 10 cigarettes per day were excluded from both studies.

Table 6 Univariate and Mulitvariate Analyses for the Outcome of BoP Reduction

	Univariate analysis					Multivariate analysis				
			95% CI					95% CI		
	Estimate	SE	Lower	Upper	*P* value	Estimate	SE	Lower	Upper	*P* value
Age	−0.024	0.026	−0.078	0.029	.362	—	—	—	—	—
Sex										
Female	0.071	0.599	−1.129	1.271	.906	—	—	—	—	—
Smoking*										
No	−0.206	0.612	−1.433	1.021	.738	—	—	—	—	—
Past history of periodontitis										
Yes	0.622	0.903	−1.188	2.432	.494	—	—	—	—	—
Arch										
Maxilla	0.496	0.583	−0.673	1.666	.399	—	—	—	—	—
Site										
Premolar	0.210	0.597	−0.986	1.407	.726	—	—	—	—	—
Previous restoration type										
Cemented	−0.350	0.572	−1.497	0.797	.543	—	—	—	—	—
KTW	−0.279	.2909	−0.862	0.303	.341	—	—	—	—	—
Treatment										
Submerged	0.085	0.565	−1.047	1.216	.882	—	—	—	—	—

*Refers to smoking < 10 cigarettes per day. Smokers who smoked > 10 cigarettes per day were excluded from both studies.

Pocket probing depth reduction (PDR)

Table 5 presents the results of the regression models for the outcome of PDR. The univariate analysis showed a significant positive association between the submerged healing reconstructive approach, baseline KTW, and the outcome. However, the multivariate analysis only confirmed a statistically significant positive association with a submerged healing approach (1.02 [95% CI (0.33, 1.10)], $P = .004$]), indicating higher PDR with a submerged approach compared to nonsubmerged healing. None of the other parameters showed a significant relationship with the outcome of PDR.

Bleeding on probing (BoP) reduction

Table 6 shows the results of regression models for BoP. None of the independent variables showed a significant association with BoP reduction in any of the models.

DISCUSSION

When it comes to treating peri-implantitis bony defects with the goal of reconstructing the lost structures, two approaches have commonly been used in the literature: submerged[10] and nonsubmerged[32] healing. The literature comparing the outcomes of these two techniques is scarce, and systematic reviews have been inconclusive.[16,27] Therefore, this reanalysis study was designed to investigate the impact of surgical-, implant-, and patient-related factors on the clinical and radiographic outcomes of surgical reconstructive treatment for peri-implantitis defects, primarily focusing on exploring prognostic factors for the treatments and whether a type of healing approach can provide significantly superior outcomes.

The feasibility of clinical and radiographic outcomes of both submerged and nonsubmerged healing approaches was previously investigated by our group relative to the outcomes of DF, RDF, PDR, and BoP reduction.[10,32] We found that the submerged group had (on average) 1.5 mm more PDR, 0.9 mm more DF, and 1.9 mm more RDF than the nonsubmerged group. This discovery was in line with a series of other studies that reported the outcomes of either a submerged or a nonsubmerged healing approach for treatment of peri-implantitis.[10,25,26,28,29,32,34–36] In a preliminary study on the submerged approach, Monje et al[35] reported a mean of 2.2 mm (ranging from 0 to 8.6 mm) of RDF and 3.7 mm of PDR (ranging from 0.7 to 5.9 mm). Similarly, Canullo et al[26] performed removal of prosthetic suprastructures to allow for submerged healing of circumferential peri-implant defects; they reported 4.5 mm of PDR and 5.1 mm of DF after 6 months. In a 7-year longitudinal study by Roccuzzo et al[34] following a nonsubmerged healing approach, the authors reported significant PDR (2.92 ± 1.73 mm) as well as BoP reduction of approximately 54%. Wiltfang et al[37] followed the same protocol and found 3.5 mm of RDF and an average of 4 mm of PDR. However, it should be noted that the lack of control groups in these studies and discrepancies in the selection of the applied bone graft (autogenous, allogeneic, xenografts, or a combination) and membranes (resorbable or nonresorbable), as well as vast differences in the follow-up intervals, does not allow for a direct comparison between the method of reconstructive approaches used in the present study.

Our analysis from data of two prospectively conducted studies in this report found superior outcomes with the submerged healing approach, showing a statistically significant positive association between complete implant submersion and PDR (estimate: 1.02, $P < .05$), DF (estimate: 0.411, $P < .001$), and RDF (estimate: 1.735, $P < .001$). Schwarz et al[38] were the first group to provide a comparison between the submerged and nonsubmerged approaches via an animal study but without regenerative therapy. Despite achieving clinical improvements in both groups, the newly formed bone-to-implant ratio was significantly higher in the submerged group, as displayed by the histomorphometric analysis.[38] In addition, radiologic improvements were only detected in the submerged group, suggesting improved treatment outcomes with that approach.

To the best of our knowledge, no previous human study has prospectively compared the outcomes of the two healing approaches. In a retrospective study by Astolfi et al,[31] the group compared the outcomes of removing or leaving the prosthesis during the healing period of peri-implantitis reconstructive surgery with the use of xenogeneic bone graft and a resorbable membrane. The RDF was 2.84 ± 1.78 mm and 2.18 ± 1.41 mm in nonsubmerged and submerged groups, respectively. However, their statistical analysis failed to prove any significant differences between the two groups. Moreover, Roos-Jansåker et al performed submerged and nonsubmerged healing approaches in two separate studies.[29,36] Their results revealed a mean PDR of 4.2 mm and DF of 2.3 mm after 12 months of follow-up in the submerged group, which was more favorable compared to the nonsubmerged group in their other study.[29,36] Additionally, in a systematic review, Daugela et al[16] reported comparable results in both groups; however, only three studies were included for the submerged group and the protocols among the studies were vastly heterogeneous. Fundamentally, the success of tissue regeneration is dependent on achieving primary wound closure, facilitating angiogenesis by means of blood clot formation as well as stability of the graft material.[39] As it relates to regenerative treatment of peri-implantitis bony defects, aside from primary wound coverage, the aspects of debridement and decontamination can be achieved more appropriately by following a submerged healing approach; the removal of prosthetic components in this approach allows for enhanced access and control over the defect. In short, it can be speculated that the common ground among the above-mentioned studies is complete wound closure, which subsequently leads to undisturbed healing and results in superior outcomes in submerged approach.

Nonetheless, submerging the implant could also cause several difficulties in the treatment workflow.[32,36] First, removal of the prosthesis (especially cement-retained crowns) can be challenging prior to the surgical intervention. Moreover, adding an extra step to the treatment, while being cost-effective and gaining patient acceptance, would also increase the challenges of the procedure.[10,31] Therefore, clinicians should pay attention to proper patient selection as well as good patient communication and awareness prior to initiation of treatment. As such, future studies

on patient-reported outcomes would serve as an advantage in the field. Additionally, keep in mind that a submerged healing approach might not be the optimal treatment for all peri-implantitis intraosseous defects.[40] Thus, when indicated, a nonsubmerged reconstructive approach for these defects with solely flap readaptation to the level of the bony crest may be appropriate. Nonetheless, note that there are some peri-implantitis defect morphologies that might not be suitable for a typical reconstructive approach, in which case neither of the discussed healing approaches can be used.[41]

The effect of included variables was also tested on the outcomes of BoP reduction in this study. However, the statistical model did not indicate any significant associations. In both the submerged and nonsubmerged groups, the BoP percentage decreased similarly and by more than 60% within the 1-year follow-up time frame. Identical mechanical surface debridement and chemical detoxification protocols were applied for both groups. Therefore, the results suggest that regardless of BoP being affected by other parameters, both healing protocols seem to provide equally effective outcomes with regard to reduction of BoP throughout the 1-year period. Furthermore, the removal of crowns in both groups might possibly contribute to this outcome as it provides enhanced access to the defect. Nonetheless, it must be noted that in many circumstances this may not be feasible because the crown may have been fabricated by another provider, and patients might not be willing to undergo payment for newly fabricated prostheses. In addition, the esthetic impact should also be accounted for in the case that the implant is located in the anterior region.

Lastly, in the present study we presented a clinical and radiographic outcome comparison between the submerged and nonsubmerged healing groups by reanalyzing the data from two previously conducted studies in a single center by the same surgeon. Nevertheless, different types of membranes were utilized for each group (dPTFE versus collagen), which may also have contributed to the previously mentioned outcomes, as well as different implant surface characteristics and a more stringent defect inclusion criteria set for the implants treated in the submerged group. It should be noted that while both groups and all implants were included only after meeting a stringent set of local and systemic patient criteria, the implants treated by the submerged treatment arm included more crater-like defects compared to a broader inclusion criterion that was applied in the nonsubmerged group; despite our efforts to control for the potential confounding effect of this variable, in the clinical setting there is no doubt that a more favorable bony defect morphology would render a superior bone regenerative outcome. Furthermore, it should be acknowledged that the operator who served as the surgeon also performed the clinical measurements at the follow-up recall and may have inadvertently introduced a bias. Indeed, attempting to compare the two groups within the framework of a randomized controlled clinical study would be ideal and can even be more powerful when regeneration is evaluated by the means of histomorphometric analyses to provide more accurate data about true peri-implant defect regeneration.

CONCLUSIONS

Within the limitations of this study, we conclude that employing a fully submerged reconstructive approach for surgical management of peri-implantitis yields significantly improved clinical and radiographic outcomes when compared to a nonsubmerged healing protocol. Thus, complete submersion of implants and the augmented sites via primary wound closure should be performed whenever possible.

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The authors declare no conflicts of interest related to this research article. They do not have any financial interest, either directly or indirectly, in the products or information listed in the paper.

The data that support the findings of this paper are available from the corresponding author upon request.

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