# Non-submerged reconstructive approach for peri-implantitis osseous defect, with removal of implant crowns: 1-year outcomes of a prospective case series study

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**Author Contributions:**

**S-C. W**: Conception and design of the study; performed the surgical procedures, initial and final drafting of the work; Final approval of the version to be published; accountable for all aspects of the work.
**S. B**: Design of the study, acquisition and interpretation of data and analyses, manuscript preparation and the initial draft, final reviewal of the work; accountable for all aspects of the work. **H-L. W**: Design of the study; critical review of the draft and contribution to the writing of the manuscript; Final approval of the version to be published and accountable to the accuracy or integrity of the work. **W-X. H**: Conception and study design, contribution to manuscript writing, critical review of the final draft, accountable for all aspects of the work.



**ABSTRACT**

**Background & Aim.** The aim of this study was to test a non-submerged reconstructive approach for peri-implantitis osseous defects, by removing the prosthetic components, augmenting of the infraosseous bony compartment, and flap re-adaptation around the replaced healing abutments, without obtaining a primary wound closure.

**Methods.** Twenty-nine implants in 24 patients were treated. Implant suprastructures were removed at the time of the intervention, to aid with the debridement process which included curettage, implantoplasty, air-power driven devices, and locally delivered antibiotics. The infraosseous part of peri-implant defects were augmented using a composite bone graft and an absorbable membrane to be secured around the replaced healing abutments without attempting to submerge the implants. After 8 months, direct peri-implant defect measurements were obtained to serve as the primary outcome. Secondary outcomes included of radiographic bone changes, and probing depth (PD) and bleeding on probing (BOP) changes at 12 months.

**Results.** At the time of the surgical re-entry (8 months), a statistically significant clinical and radiographic defect fill was observed (average of 2.33 mm, and 1.63 mm, respectively).

Approximately 3 months after crown replacement, 12 months from the surgical intervention, a significant PD (1.51 mm) and BOP (65%) reduction were also noted.

**Conclusions.** Considering its limitations, the utilized non-submerged approach (with removal of implant crowns) led to significant improvements in clinical (defect fill, PD, BOP) and radiographic outcomes.

**Key words:** Dental Implants, Peri-Implantitis, Bone Regeneration, Alveolar Ridge Augmentation, Evidence-Based Dentistry, Periodontal Diseases



## 1. Introduction

Dental implants have become increasingly popular therapies for predictable replacement of missing teeth[1]. In fact, a study analyzing data from 7 National Health and Nutrition Examination Surveys (NHANES) from 1999 to 2016, reported that the application of dental implant therapy for adults with missing dentition was significantly on the rise, and projected that by the year 2026, the estimated proportion of patients who had received an implant would be about 23% (from 0.7% in by the year 2000)[2]. Considering this rise and popularity in dental implant treatment, it is crucial to acknowledge and study the complications that may accompany these procedures. These can include the onset of peri-implant diseases which can eventually lead to the loss of the implant itself [3-7], or esthetic challenges in the presence of implant health such as the occurrence of peri-implant soft tissue dehiscence/deficiencies [8-11].

Perhaps the most studied and challenging implant-related complication is the occurrence of peri-implant diseases [12], in particular peri-implantitis which starts as an the inflammatory response around a dental implant leading to loss of its supporting bone [4, 6]. While the prevalence rate of this disease varies across the literature [3, 13], it is generally estimated that peri-implantitis affects just about 25% of the population with dental implants [12, 14] and is also the main cause of implant failure [7, 15, 16]. A

longitudinal study by Derks and colleagues showed that 52% and 66% of implants were affected by peri-implantitis just after 2 and 3 years, respectively, while 70% and 81% of patients were diagnosed with peri-implantitis over the same respective periods of time [17].

Relative to their treatment, by now it is generally known that non-surgical therapies alone are insufficient for dealing with this emerging disease [18, 19, 19-21] and many have accepted that surgical intervention is needed to provide access to the implant surfaces and the peri-implant defect to aid in detoxification and localized debridement [20, 21]. Nevertheless, surgical access therapy alone has failed to predictably provide satisfactory results [21-23, 24]. In fact, a recent longitudinal study among 130 surgically treated peri-implantitis defects showed that there was a 44% chance of disease recurrence, or even progression at 5 years, with 27 of the implants that were extracted [25]. Nevertheless, even with complete disease resolution after surgical treatment, the previously affected implant is devoid of its original supporting bone due to the irreversible nature of the disease [6]. Hence, the rise of reconstructive therapies for peri-implantitis to regain the lost peri-implant supporting bone as well as achieving disease resolution [26-28, 29-32]. Therefore, the aim of this study was to evaluate a novel surgical method with a non-submerged protocol for augmentation of peri-implant infraosseous defects.

## 2. Materials and Methods

### 2. 1. Study registration, design, and Participants

The current study was designed to test the outcomes of a non-submerged regenerative protocol for the treatment of peri-implantitis osseous defects, facilitated by removal of implant crowns and replacement with healing abutments at the time of the surgical procedure. The study protocol was in full accordance with the Declaration of Helsinki of 1965, as revisited in Tokyo in 2013 and approved by the by the Institutional Review Board and the local ethical committee (Stomatological Hospital of Xiamen Medical College, #18950051616). All clinical steps and procedures of the study were carried out at a private office in Taipei, Taiwan. This manuscript is prepared following the items presented in the STROBE statement (www.strobe-statement.org, checklist provided as a supplementary file).

### 2. 2. Eligibility Criteria

From January 2017 to December 2020, patients with a confirmed diagnosis of peri-implantitis [6] in at least one bone-level titanium dental implant in the posterior region who had been on previous maintenance therapy either at a university or private practice (in Taipei, Taiwan) were assessed for

recruitment. The diagnosis of peri-implantitis was according to the 2017 World Workshop[6]. Briefly, this included an implant with bleeding and/or suppuration on probing (BOP/SUP), increased peri-implant probing depths (PDs) compared to previous examinations, and radiographic bone loss beyond initial biological bone remodeling[6]. In the absence of previous data, the diagnosis of peri-implantitis was based on the presence of BOP and/or SUP, with PD of 6 mm or more, with at least 3 mm of radiographic bone loss[6].

The following were set as exclusion criteria: a) any uncontrolled/untreated (ongoing or active) systemic or periodontal disease, or patients taking medications that could alter bone metabolism, or interfere with normal wound healing, b) any recent (within 2 months) antibiotic therapy, c) pregnancy, d) smoking more than 10 cigarettes per day, e) unable to maintain an adequate oral hygiene (O'Leary plaque index more than 20%) [33], f) mobile dental implants, g) implants placed completely outside the bony housing or presenting with a complete horizontal pattern of bone loss, and h) any other contraindications for undergoing a dental surgery.

After fulfillment of the above criteria, details of the study were explained to all patients, followed by obtaining an informed consent and providing instructions on oral hygiene.

### 2. 3. Study protocol

#### 2. 3. 1. Surgical visit (Visit 1)

Figure 1 describes the protocol of this study and its timeline. The surgical treatment occurred approximately 4 weeks after completion of an initial round of localized non-surgical debridement of the infected implant(s) that were to be treated as part of the study.

At the start of the surgical visit, a single calibrated operator (S-C.W) recorded the following clinical measurements (which were to be re-taken and compared with the final visit (V3)) from all osseous defects: PDs, as measured from the margin of the implant mucosa to the depth of the probable pocket at 6 implant sites of disto-buccal, buccal, mesio-buccal, mesio-lingual, lingual/palatal, disto-lingual, using a periodontal probe‖ in the units of millimeters, as well as BOP and SUP that were recorded dichotomously as yes/no within 30 seconds of gentle probing; and plaque index (PI) (0 to 3) [33].

All surgical procedures were performed by the same experienced surgeon (S-C.W) under local anesthesia, similar to a previously reported protocol [34, 35]. The implant prosthetic components (implant crowns and abutments) were first removed to allow for enhanced surgical access to the areas and to aid with the debridement process (curettage, implantoplasty, air-power driven devices, and locally delivered antibiotics) and potentially with the reconstructive approach. All patients were advised to change or modify their existing crowns to facilitate their hygiene and to avoid disease recurrence, 20 patients agreed to have a new crown but 4 declined due to financial reason. Next, an intrasulcular incision was placed around the implants to reflect a full thickness mucoperiosteal flap on both buccal and lingual/palatal sides. Vertical releasing incisions used if indicated and placed at a distance of at least one tooth/implant away from the surgical site.

### 2. 3. 2. Implant detoxification and defect debridement

The surrounding implant defects were first debrided using periodontal curettes¶ to remove all granulomatous tissues. Next, implantoplasty was performed on the exposed threads using rotary instruments# under copious saline irrigation [36], followed by the application of an air-abrasive device with glycine powders** [37]. Lastly, an antimicrobial agent (Tetracycline, 250 mg mixed in 2.5cc saline) was applied on the implant surfaces for three minutes [34, 35, 38].

### 2. 3. 3. Clinical measurements of implant infraosseous defects

After through peri-implant defect degranulation and surface detoxification, a periodontal probe‖ was used to obtain direct clinical measurements of the vertical component of the implant infraosseous defects at 4 exact areas (buccal, lingual/palatal, mesial, distal). At each implant site, the most coronal aspect of the platform served as the initial reference point for comparison, until the depth of the bony defect, at which would be the most top portion of the bone-to-implant contact at that site.

### 2. 3. 4. Augmentation of osseous defects

Several perforations were made on the surrounding cortical bone using a ¼ round bur [34, 35, 39]. Next, similar to previous reports [34, 35, 39, 40], a bone graft mixture containing approximately 60% freeze-dried bone allograft¶¶, 20% mineralized bovine bone particles##, and 20% autogenous bone (obtained with

a bone scraper from either an adjacent ramus or the maxillary tuberosity) was used to fill the infraosseous component of all peri-implant defects, making sure impede entrance of the graft particles inside the implant fixture. An appropriate-size collagen membrane†† was then trimmed and placed to cover the grafted areas, leaving a small perforation on the membrane (on the area corresponding to the implant fixture(s)) to allow for installment of an appropriate size healing abutment through the applied membrane. Minimal periosteal-releasing incisions were placed, if needed to ensure a passive flap adaptation and tension-free flap closure. After ensuring a stable and complete coverage of the defects, the flap was re-adapted, using single interrupted and horizontal mattress sutures§§ to cover the grafted peri-implant regions, making a seal around the healing abutments, while leaving the abutments exposed without fully submerging the implants.

**2. 3. 5. Post-operative regimen and recall intervals**

All patients were provided with systemic antibiotic prescriptions to be taken orally for 10 (500 mg amoxicillin every 8 hours), or 5 days (6 Zithromax 250 mg tablets, to be taken 2 on the first day, and once daily thereafter) as well as a prescription for analgesics as needed (600 mg of ibuprofen) [34, 35]. Specific Oral hygiene instructions were also instructed to patients along with through written post-op directions.

For the first 2 weeks, patients were also advised to rinse with a chlorhexidine-containing mouthwash (0.12% Chlorhexidine mouth rinse) twice a day.

The initial post-operative recall was at 14 days for removal of sutures, followed by the next visits to check the healing of all treated sites and reinforce hygiene instructions at 6 weeks, 4 months, and 6 months after the procedure.

**2. 3. 6. Re-entry visit at 8 months (Visit 2)**

At 8 months following the surgical treatment, a re-entry procedure was performed, at which point, a full thickness flap was elevated to gain access and evaluate the augmented sites and the treated osseous defects. It was planned that if the reconstructive approach was not successful and peri-implant defects remained, additional reconstructive therapy would be performed at this stage. The healing abutments were also removed to obtain peri-implant defect measurements relative to the implant platform, as similarly performed during the surgical treatment. The healing abutments were re-placed,

followed by interrupted sutures for flap adaptation, which were removed after 2 weeks of healing time. At this time, new crowns were fabricated and delivered to 20 patients who agreed to have new crown replacement and the remaining 4 patients, the contours of implant crowns were adjusted to facilitate hygiene and maintenance.

Subsequently, all participants were enrolled in a 3-month maintenance program, of which the initial 3-month recall after installation of the crowns served as the final study time point (Visit 3)

**2. 3. 7. Final recall (Visit 3)**

Three months after replacement/re-shape of crowns, measurements of PD were obtained similar to the surgical visit (V1), to compare with the pre-treatment baseline.

Figure 2 displays the steps taken for a treated case, as part of this treatment protocol.

**2. 4. Study outcomes**

**2. 4. 1. Primary endpoint**

As with a previous report from our group[35], the primary outcome of this study was to assess changes in linear measurements of clinical defect fill (bone gain) from V1 to V2, as a result of the surgical reconstructive treatment after 8 months. This was termed the clinical vertical defect fill (DF), and assessed at each 4 implant sites (buccal, lingual/palatal, mesial, distal):

DF = (Measurement at the surgical treatment) – (Measurement at 8-month re-entry procedure)

The mean changes at the 4 implant sites were also calculated to represent the implant score showing the mean DF per implant.

**2. 4. 2. Secondary endpoints**

**2. 4. 2. 1. Radiographic bone gain:**

To assess the changes in the radiographic bone levels, all participants had also received two identical cone-beam computed tomography (CBCT) scans‡‡. The CBCT scans were obtained at V1 (prior to

the surgical treatment), and at V2 (at the 8-month re-entry visit), as per manufacturer instructions (90 kv, 3.2 mA, 15 s, 685 mGy.cm$^2$, Voxel size: 150 μm x 150 μm x 150 μm) to observe radiographic changes at all 4 implant sites, similar to the direct clinical measurements obtained for the peri-implant defects. As such, the highest point of each implant platform served as the initial reference, until the first visible bone-to-implant contact [35].

A calibrated radiologist (C-Y.W) performed the radiographic evaluations and the defect measurements at both time points (V1 and V2) to obtain the changes at each implant site to provide for the vertical radiographic defect fill (RDF):

RDF = (Measurement at the per-surgical appointment) – (Measurement at 8 months)

Similar to the outcome of DF, the changes of the four peri-implant sites were averaged to obtain each implant score.

Careful attention was paid during this CBCT assessments to ensure reproducible measurements of all osseous defects, as previously described [35], following a prior calibration and an intra-examiner reproducibility of at least 0.85.

**2. 4. 2. 2. Peri-implant probing depth (PD) and BOP changes:**

Changes in PD from V1 (prior to surgical treatment) to V3 (3 months after re-installment of crowns) were calculated to obtain the PD reduction at each of the six measured peri-implant sites as follows:

PD reduction = (Measurement at pre-surgical appointment) – (Measurements at the final recall)

The average changes of the six peri-implant PDs were also obtained for descriptive purposes.

BOP was assessed dichotomously (Yes/No) at both time points, for any implant that presented with a positive BOP at any of the six sites and expressed as a percentage of the total treated implants at the specific time point.

**2. 5. Outcome assessment and statistical analysis**

Descriptive statistics were performed by obtaining means with standard deviations (SD) for continuous measures of DF, RDF, and PD for presentation of clinical and radiographic data. BOP was

assessed dichotomously and expressed as a percentage of implants with a site of bleeding at V1, and compared to the final recall (V3).

To assess statistical inferences for changes in the primary outcome of DF, and our secondary endpoints of RDF and PD measurements with respect to time, linear mixed-regression models were produced to account for repeated measures with random effects for patient, implant within patients, and the implant site of measurement per implant in patients (a three-way interaction) and with a fixed effect for time. Model coefficients were recorded, along with their confidence intervals (CIs) to convey the rate of change for each endpoint with respect to time. Model assumptions were tested, and a *p* value threshold of 5% was set for statistical significance. For descriptive purposes, the average change in DF, RDF, and PD were also obtained per implant

All data analysis was performed by a separate study team member with experience in statistical analysis (S.B), who had not participated in the clinical measurements or collection of data, using a specified software ***, and the statistical packages lme4 [41], and dplyr [42].

## 3. Results

### 3. 1. Population and implant characteristics

Twenty-four patients, including 17 males and 7 females with a mean age of 56.8 ± 13.1 completed the study. This included a total of 29 bone-level implants with osseous defects that were treated, all in the posterior region (10 at premolar sites, and 19 at molars). All implants had been in function for at least 2 years prior to the diagnosis of peri-implantitis. Five patients had more than one implant treated, while the rest all had only a single implant that was treated. Sixteen of the treated implants were located in the mandible, and 13 in the maxilla. Only five patients reported the use of tobacco which was less than 5 cigarettes per day, however most of the patients had a history of periodontal disease and/or treatment for a periodontal condition at some point. The characteristics of the treated sample are presented in table 1.

All participants were compliant to the prescribed medications and the study follow-up recalls, and healing at all sites was uneventful without the occurrence of any unexpected or major complications.

### 3. 2. Primary outcome of direct measurements of linear bone gain

Table 2 presents the rate of change with respect to time for all outcomes of the study, according to the results of the mixed model.

At the time of the surgery, the average clinical measurements of the peri-implant osseous defects were 6.14 ± 1.38 mm, 6.03 ± 1.48 mm, 6.05 ± 1.73 mm, and 5.64 ± 1.27 mm on the buccal, lingual/palatal, mesial, and distal sites, respectively. At the surgical re-entry after 8 months, the obtained measurements for the same peri-implant sites were 3.6 ± 1.78 mm, 3.72 ± 1.71 mm, 3.55 ± 1.92 mm, and 3.66 ± 1.7 mm, respectively.

According to the results of the mixed model (table 2), the changes in all the sites were statistically significant, amounting to 2.53 ± 2.02 mm in clinical bone gain on the buccal sites, 2.31 ± 1.91 mm on the lingual/palatal, 2.51 ± 1.84 mm on the mesial, and 1.98 ± 1.74 mm on the distal sides.

Table 3 presents the average gain and reduction of all clinical parameters and their respective time points. As shown, the mean gain for the implant sites amounted to 2.33 ± 1.8 mm at 8 months after surgical augmentation.

### 3. 3. Radiographic (CBCT) bone gain:

Prior to the surgical treatment, the peri-implant osseous defects presented with radiographic measurement of 5.48 ± 1.47 mm, 5.29 ± 1.16 mm, 5.18 ± 1.45 mm, and 4.97 ± 1.19 mm on average for the peri-implant sites of buccal, lingual/palatal, mesial, and distal, respectively. The corresponding assessment of the same implant sites at V2 (8 months after the surgical treatment) resulted in 3.63 ± 1.91 mm, 3.75 ± 1.8 mm, 3.42 ± 1.81 mm, and 3.57 ± 1.72 mm, respectively. According to the mixed model all changes were statistically significant, amounting to RDF of 1.84 ± 2.06 mm on the buccal aspect of implants, 1.54 ± 1.93 mm on the lingual/palatal aspects, followed by 1.76 ± 1.43 mm, and 1.39 ± 1.38 mm on the mesial and distal sites, respectively ($p$ values <0.001, table 2). In addition, the overall implant score for RDF was of 1.63 ± 1.70 mm (table 3).

### 3. 4. Peri-implant probing depth reduction and bleeding on probing:

The initial measurements of PD prior to removal of implant suprastructures averaged to 4.66 ± 1.37 mm, 5.1 ± 1.21 mm, 4.72 ± 1.19 mm, 4.52 ± 0.99 mm, 4.79 ± 0.9 mm, and 4.59 ± 1.24 mm on the mesio-buccal, buccal, disto-buccal, disto-lingual, lingual, and mesio-lingual sides, respectively. Three

months after installment/re-shape of new/old prostheses, the corresponding values amounted to 3.17 ± 1.07 mm, 3.59 ± 0.82 mm, 3.17 ± 1.08 mm, 2.84 ± 1.37 mm, 3.36 ± 0.78 mm, and 3.16 ± 0.89 mm, respectively.

The reduction in all PD measurements from baseline to the final visit was statistically significant, amounting 1.48 ± 1.27 mm, 1.51 ± 1.12 mm, 1.55 ± 0.94 mm, 1.67 ± 1.43 mm, 1.43 ± 1.04 mm, and 1.43 ± 1.22 mm for the peri-implant regions of mesio-buccal, buccal, disto-buccal, disto-lingual, lingual, and mesio-lingual sides, respectively ($p$ values <0.001, table 2). The average amount of implant PD reduction was 1.51 ± 1.17 mm (table 3). In addition, a significant BOP reduction was also observed (from 100% to 34.5%).

**4. Discussion**

At present, most of the evidence on the reconstructive therapy for peri-implantitis osseous defects originates from studies with a non-submerged regenerative approach where crown removal is not performed and thus achieving a primary wound coverage is not possible [29-32, 43, 44]. Fewer studies have also employed a submerged healing with the aid of removing implant suprastructures, adopting the principle of primary wound closure from guided bone regeneration, and leaving the implants fully submerged throughout the entire duration of the regenerative therapy[27, 45]. Indeed the added step of crown removal can present a challenge on its own, in particular, with cement-retained prostheses, where a new crown may need to be fabricated. Additionally, not all peri-implantitis cases may be suitable for regeneration. As a matter of fact, studies have shown that while many of the peri-implant defects tend to be circumferential and contained in nature, a variety of other defect morphologies can also occur as a result of the peri-implant disease [46, 47], some of which may not be suitable for attempting a typical reconstructive approach [13, 48].

In the present study, we tested a reconstructive approach for peri-implantitis, with removal of all prosthetic components to facilitate the debridement process, while attempting regeneration/ reconstructive only for the infraosseous portion of the bony defect. After treatment, all implants were replaced with healing abutments so we could reposition the flap around the abutments to cover the augmented sites, without fully submerging the treated implants or obtaining a primary wound closure. As a result, we observed statistically significant improvements in all outcomes, including clinical and radiographic defect fill at 8 months (average DF of 2.33 mm, and RDF of 1.63 mm), as well as significant PD (1.51 mm) and BOP reduction (65%) at 12 months. To the best of our knowledge, no previous study has described such protocol for treating peri-implantitis. Therefore, despite the fact

that we observed significant improvements in all outcomes, a direct comparison of our results to the literature may not be feasible.

In a recent study from our group, thirty implants with peri-implantitis were treated with a fully submerged regenerative approach [35]. At 8 months, we noted a significant clinical bone gain of 3.22 mm (DF) and radiographic defect fill of 3.47 mm (RDF), as well as PD and BOP reduction of 2.93 mm, and 63%, respectively, at 12 months[35]. In the stated report, all implant prosthetic components were removed, and only replaced after at least 8 months of uninterrupted submerged healing, having obtained a primary wound closure at the surgical intervention which was maintained throughout the entire healing period. Additional differences of that study to the current research, are the application of a non-resorbable dense polytetrafluoroethylene (dPTFE) membrane which covered the implant fixtures and the augmented sites, in contrast to the collagen membrane that was placed to surround the implants' healing abutments in this study. Another important difference was the inclusion of strictly contained and crater-like defects (with a vertical defect of at least 3 mm) in the previous report [35] compared to a broader inclusion of peri-implant defects in the present study, which could also led to difference results. Indeed, a recent study evaluating the outcomes of surgically treated peri-implant defects, found that the morphology and pattern of bone loss at baseline significantly influenced the surgical results of both regenerative and resective procedures [49]. Considering the advantages of each of the mentioned variables on the outcomes of bone regeneration [50-52], it is plausible that the higher DF, RDF and therefore the greater PD reduction could be attributable to any, or all of the aforementioned differences collectively.

From another standpoint, an aspect to bear in mind is the similar BOP reduction of about 65% in both studies. Considering our stringent criteria for this assessment (such that even a single BOP-positive site per implant would render the implant BOP-positive), it can be assumed that the part of implant surface debridement and defect detoxification, at least in the short-term was equally effective. This is likely due to the combination of the mechanical and chemical debridement that was performed using periodontal curettes, implantoplasty, an air-abrasive device with glycine powders and lastly a locally delivered antimicrobial agent, all of which were facilitated in both studies by the enhanced access provided by removal of implant crowns.

Indeed, for a more accurate comparison of the submerged and the applied non-submerged treatments, a multi-arm study design would have been ideal, in which all patients and the infected implants could have randomly received either treatment. While this has not yet been performed in a human clinical trial, Schwarz et al. compared the submerged and non-submerged regenerative treatments on thirty

ligature-induced peri-implantitis lesions in an animal model [53]. While both treatment groups at 3 months led to significant improvements in all clinical outcomes, the implants which had received the submerged treatment reportedly obtained better results and showed greater re-osseointegration potential [53]. Another study that utilized a submerged regenerative approach for peri-implantitis, by Roos-Jansåker and colleagues found 2.3 mm radiographic defect fill at 6 months [45], compared to a previous report from the same research group which had included a non-submerged treatment approach, and observed less favorable results [54]. The authors of the study also speculated that the undisturbed wound healing due to a submerged regenerative approach could have led to the superior results. Therefore, it can be safely assumed that, when possible, a submerged regenerative approach would enhance the outcomes. Nevertheless, as previously mentioned, not all peri-implantitis defects bear similar or uniform patterns of bone destruction, thus a direct comparison of either treatments may in fact not be plausible. Therefore, a regenerative approach for the infraosseous defect component, with merely flap re-adaptation to the level of the bony crest may be suitable, as presented in this report.

Among the limitations of this study, the lack of a customized stent for performing standardized measurements is to be acknowledged, as well as absence of a positive or negative control group. Nonetheless, considering the recent literature that verifies the benefit of a reconstructive treatment over surgical access flap therapy alone[55, 56], and the relapse rates associated with the latter approach [25], future studies should aim to compare the reconstructive potential and long-term benefit of different biomaterials, as a consensus on ideal biomaterials for peri-implantitis treatment is currently lacking [56]. Additionally, it should be noted that true and definitive regeneration can only be assessed via histological analyses, which was not done in this report. Hence, a reconstructive term was used in this study instead. At last, we deem necessary randomized clinical trials for directly exploring and comparing other aspects of reconstructive therapies for peri-implantitis, such as subjective patient-reported outcome measures, esthetics, and relapse or re-infection of the successfully reconstructed bone.

## 5. Conclusion

Within the limitations of this study, we conclude that a non-submerged reconstructive approach for the treatment of peri-implantitis osseous defects can lead to significant improvements in clinical (peri-implant bleeding probing depth reduction) and radiographic outcomes (CBCT), in particular the reconstruction of the intraosseous peri-implant supporting bone. Additionally, we report that the

removal of implant crowns can facilitate peri-implant defect debridement, implant surface detoxification, and enhance the surgical access for performing the reconstructive therapy.



**Footnotes**

‖ PCP-UNC 15; Hu-Friedy®, Chicago, IL, USA

¶ Gracey curettes; Hu-Friedy®, Chicago, Illinois, US

# Meisinger, Hager & Meisinger, Neuss, Germany

** AirFlow®, EMS, Nyon, Switzerland

†† Jason Pericardium membrane, Botiss biomaterials, Zossen, Germany

‖‖ Master Pins, Osteogenics Biomedical, TX, USA

¶¶ Maxgraf, Botiss biomaterials, Zossen, Germany

## Cerabone, Botiss biomaterials, Zossen, Germany

§§ Vicryl, Ethicon, Johnson& Johnson, Somerville, NJ, USA

‡‡ Carestream Dental LLC, CS 8100 3D, Atlanta, GA, USA

*** Rstudio Version 1.1.383, Rstudio, Inc., Massachusetts, USA

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**Data availability:** The data that support the findings of this study are available from the corresponding author upon request.



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**Tables and Figures Legends**

**Table 1.** Demographic of the treated population cohort.

| Category | Characteristic | Value |
|---|---|---|
| Patient | Males (n, %) | 17, 70.8% |
| | Age (mean ± SD) | 56.8 ± 13.14 years |
| | Smokers* (n, %) | 5, 20.8% |
| | Previous history of periodontal disease or treatment (n, %) | 22, 91.6% patients |
| Implant | Maxilla (n, %) | 13, 44.8% |
| | Mandible (n, %) | 16, 55.2% |
| | Premolar region (n, %) | 10, 34.5% |
| | Molar region (n, %) | 19, 65.5% |
| | Screw-retained restorations (n, %) | 10, 34.5% |
| | Cement-retained restorations (n, %) | 19, 65.5% |

n corresponds to the number of patients/implants based on the category presented in the left column, SD, standard deviation,

*The 5 smoking patients all reported smoking less than 5 cigarettes per day

**Table 2.** Results of the mixed models conveying the rates of change with respect to time for the outcomes of the study.

| Parameter | Peri-implant site | Model coefficient (mm) | Standard error | 95% Confidence intervals (Lower, Upper bound) | *p* value | Study visits |
|---|---|---|---|---|---|---|
| Clinical vertical defect measurements | Buccal | -2.534 | 0.355 | -3.24, -1.82 | <0.001 | Visits 1 and 2 |
| | Lingual | -2.311 | 0.353 | -3.01, -1.61 | <0.001 | |
| | Mesial | -2.510 | 0.342 | -3.19, -1.82 | <0.001 | |
| | Distal | -1.982 | 0.323 | -2.62, -1.33 | <0.001 | |
| Radiographic vertical defect measurements | Buccal | -1.844 | 0.367 | -2.57, -1.11 | <0.001 | Visits 1 and 2 |
| | Lingual | -1.537 | 0.359 | -2.25, -0.81 | <0.001 | |
| | Mesial | -1.762 | 0.265 | -2.29, -1.23 | <0.001 | |
| | Distal | -1.393 | 0.256 | -1.91, -0.87 | <0.001 | |
| Peri-implant probing depth measures | Mesio-buccal | -1.482 | 0.236 | -1.95, -1.01 | <0.001 | Visits 1 and 3 |
| | Buccal | -1.517 | 0.208 | -1.93, -1.11 | <0.001 | |
| | Disto-buccal | -1.551 | 0.174 | -1.89, -1.21 | <0.001 | |
| | Disto-lingual | -1.672 | 0.265 | -2.21, -1.14 | <0.001 | |
| | Lingual | -1.431 | 0.193 | -1.81, -1.04 | <0.001 | |
| | Mesio-lingual | -1.431 | 0.225 | -1.88, -0.97 | <0.001 | |

mm, millimeter

Note that changes for clinical and radiographic vertical defect measurements, negative coefficients represent gain in the observed outcomes, while for probing depth measures negative scores represent reduction in scores.

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| Outcome | Study visits (time point) | | | |
|---|---|---|---|---|
| | Visit 1 (baseline) | Visit 2 (8 months) | Visit 3 (12 months) | Changes* |

**Table 3.** Average changes in the clinical outcomes.

| | | | | |
|---|---|---|---|---|
| DF (mm ± SD) | 5.97 ± 1.46 | 3.63 ± 1.78 | | 2.33 ± 1.88 |
| RDF (mm ± SD) | 5.23 ± 1.32 | 3.59 ± 1.81 | | 1.63 ± 1.7 |
| PD (mm ± SD) | 4.73 ± 1.15 | | 3.22 ± 1 | 1.51 ± 1.17 |
| BOP (%) | 100% | | 34.5% | 65.5% |

mm, millimeter; SD, standard deviation

DF, clinical vertical defect fill reported as the average of the 4 peri-implant sites

RDF, radiographic vertical defect fill reported as the average of the 4 peri-implant sites

PD, peri-implant probing depth reported as the average of the 6 peri-implant sites

BOP, bleeding on probing assessed dichotomously per implant for any of the six peri-implant site that presented with bleeding at the time of assessment. Changes in BOP are represent percentage in reduction

*Note that changes for DF, and RDF are calculated through subtraction of the initial time point from the secondary time point.

Changes in PD are calculated convey reduction scores as subtraction of the secondary time point from the initial time point.

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**Figure 1.** Timeline of the current study.

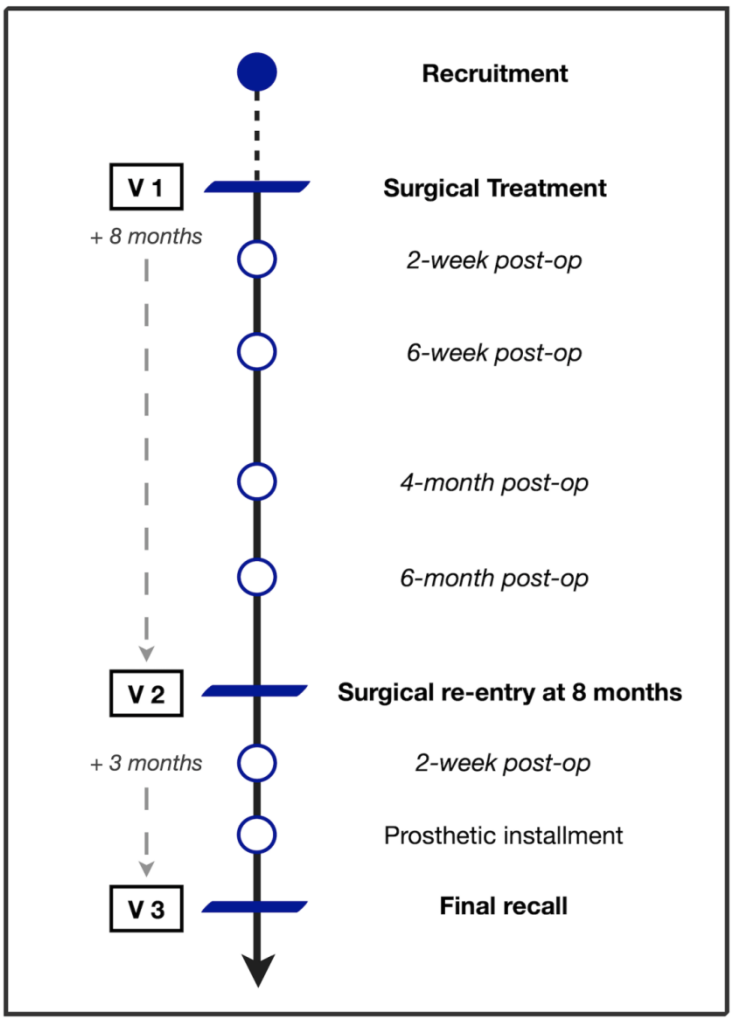

**Figure 2.** A and B) Frontal and occlusal clinical photos prior to surgical intervention (V1). C) The intraosseous defect after the completion of implant surface detoxification and peri-implant defect debridement, at the time of defect measurements. D) Defect filled with a composite bone graft. E) application of an absorbable collagen membrane. F) Flap repositioned with sutures. G) clinical photo at the time of the surgical re-entry after 8 months of healing (V2). H) Obtaining clinical measurements 3 months after the installment of implant crowns. I) Assessment of radiographic images at V1 prior to treatment, and J) at V2, prior to surgical re-entry.