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Five-Year Follow-Up of 8 and 6 mm Locking-Taper Implants Treated with a Reconstructive Surgical Protocol for Peri-Implantitis: A Retrospective Evaluation

Giorgio Lombardo [1], Annarita Signoriello [1,*], Mauro Marincola [2], Estevam Augusto Bonfante [3], Antonio Díaz-Caballero [4], Nicolò Tomizioli [1], Alessia Pardo [1] and Alessandro Zangani [1]

[1] Dentistry and Maxillo-Facial Surgery Unit, Department of Surgery, Dentistry, Paediatrics and Gynaecology (DIPSCOMI), University of Verona, 37134 Verona, Italy; giorgio.lombardo@univr.it (G.L.); nicolotomizio@gmail.com (N.T.); alessia.pardo@univr.it (A.P.); zangani.alessandro@gmail.com (A.Z.)
[2] Dental Implant Unit, Research Department, Faculty of Dentistry, University of Cartagena, Cartagena 130001, Colombia; mauromarincola@unicartagena.edu.co
[3] Department of Prosthodontics and Periodontology, Bauru School of Dentistry, University of Sao Paulo, Bauru 05508-060, Brazil; estevamab@yahoo.com.br
[4] Gitouc Research Group, Faculty of Dentistry, University of Cartagena, Cartagena 130001, Colombia; adiazc1@unicartagena.edu.co
* Correspondence: annarita.signoriello@univr.it; Tel.: +39-0458124867; Fax: +39-0458027437

Abstract: Peri-implant infections, in the absence of adequate treatment, can finally lead to premature loss of the implant. Among targeted protocols recently proposed for the treatment of peri-implant bone defects, and in the case of short implants, reconstructive surgery represents a recommended option. The purpose of this study was to evaluate the outcomes, in terms of maintenance, of a reconstructive treatment for peri-implantitis in locking-taper plateau-design single-crown implants, followed for 5 years after surgery. A retrospective evaluation was conducted in 20 patients treated with access flap surgery, concomitant chemical and mechanical surface decontamination, and bone grafting (using a self-hardening mixture of bone substitutes and biphasic calcium sulfate without the use of membranes). Of the 21 implants assessed, 9 were 8 mm-length, and 12 were 6 mm-length. Implant loss and treatment success were, respectively, 0% and 80.95% after 5 years from surgery. All parameters related to bone levels and soft tissue conditions significantly improved after 3 years and remained stable at the 5-year follow-up. The proposed protocol, followed by an effective supporting periodontal therapy, demonstrated the maintenance of the function of all implants, providing adequate stability during the healing process after surgery and limiting the onset of disease recurrence.

Keywords: crown-to-implant ratio; implantology; maintenance; peri-implant disease; prosthodontics; reconstruction; short

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1. Introduction

The placement of standard-length implants in deficient alveolar bone could sometimes represent a problematic issue and may require additional major surgical procedures to augment bone levels [1]. In the case of atrophic edentulous ridges, with great pneumatization of maxillary sinuses or post-extractive resorption of mandibular crests [2], the use of short implants was suggested as a minimally invasive approach to avoid the need for bone augmentation procedures and thus simplify the treatment [3–5]. The relatively shorter length of these implants was earlier associated with an increased failure rate, as implants placed in poor bone density were characterized by machined surfaces [6]. Nevertheless, a consistent number of recent publications demonstrated similar implant survival and success for short and standard implants with textured surfaces [7–10]. Despite higher crown-to-implant ratios (CIRS) usually characterize these implants to compensate for bone

loss and re-establish proper occlusal vertical dimension [11], their current outcomes regarding implant survival, comparable to those of standard implants, revealed them as a valid and effective alternative to more invasive procedures [3].

Peri-implantitis in short and ultra-short implants [12] represents a critical issue, considering that moderate bone loss could be definitively harmful around an implant with reduced length. A rapid deterioration of supporting crestal bone leads to increased clinical CIR (where the reference is placed at the most coronal bone-to-implant contact point position [13]), whereas changes in anatomical CIR (where the reference is placed at the interface between the implant shoulder and the crown-abutment complex) are not observed. It is important to distinguish anatomical from clinical CIR [11,14] since the latter seems to give a more realistic description of biomechanical mechanisms involved in the effects of augmented CIR on eventual prosthetic complications. Representing CIR as a key factor for implant success, according to the European Association of Osseointegration [15], the ideal value for CIR in implant-supported prostheses should be less than or equal to 2. Due to frequent situations with advanced ridge atrophy, a clinical CIR greater than 2 can often be encountered with short and ultra-short implants at the time of loading [16]. Even if several authors demonstrated that CIR greater than 2 does not seem to influence the clinical performance in both cases of standard [13] and short implants [14], a significant correlation for short implants was found between clinical CIR greater than 3.10 and 3.40 and, respectively peri-implant bone loss and implant failure [17].

Even if single crown rehabilitations in short implants present advantages in terms of oral hygiene accessibility both for the patient and the dentist, the crown can act as a lever, creating a bending moment and transferring higher stress to peri-implant bone levels [18–20], with consequent augmented risk for marginal bone loss [21]. According to finite element analysis [22,23], even a clinical CIR of 2.5 may result in an increased risk of crestal bone loss, microrotations, and marginal bone fracture in the case of a short implant supporting a single crown. When a peri-implant inflammatory process takes place [24], these values could be easily overcome, and, in the absence of adequate treatment, a premature and rapid exfoliation of the implant may occur. For short implants supporting single crowns [25], all reported failures occurred as a sudden loss of stability of the implant-crown unit, which required its immediate removal, and implant loss was related to a probable fracture of the supporting bone instead of a progressive loss of marginal bone.

Up-to-date literature [26,27] shows a considerable number of studies regarding protocols for the treatment of peri-implantitis in standard-length implants, while description of procedures to treat short and ultra-short implants, especially supporting single crowns, is still very scarce [28,29]. Plus, studies reporting long-term maintenance following reconstructive surgical therapy of peri-implantitis are limited [30–34] and have conflicting results [35]. Nevertheless, it was suggested [36,37] that after reconstructive surgical protocols, improved clinical and radiographic outcomes can be obtained and revealed as stable over time around standard-length implants if low plaque and bleeding scores are controlled using effective and frequent oral hygiene procedures. Since resective osseous surgery with implanto-plasty is not recommended for the treatment of peri-implantitis in short and ultra-short implants, the remaining options are limited to reconstructive surgery or implant removal [38,39]. Clinical and radiographic results of a surgical reconstructive protocol for the treatment of advanced peri-implantitis in standard, short, and ultra-short single-crown locking-taper implants were evaluated after 3 years of follow-up [40]. The proposed treatment, including open-flap debridement, chemical and mechanical decontamination of the implant surface, bone grafting, and transgingival healing without the use of membranes, was effective in arresting disease progression, achieving high implant survival and good clinical and radiographic conditions. Even if data from current studies seem to indicate that disease progression could be delayed in the long term for most treated implants, a percentage of them can instead show recurrence or progression of peri-implantitis after treatment [31].

According to the abovementioned considerations, the aim of the present study was to evaluate 5-year clinical and radiographic outcomes, in terms of maintenance, of a

reconstructive surgical protocol for the treatment of peri-implantitis around locking-taper and plateau-design 8 mm and 6 mm-length implants supporting single crowns. More precisely, the main outcome of the study was treatment success, assessed together with secondary outcomes regarding bone level variations and soft tissue conditions.

2. Materials and Methods

2.1. Study Design and Inclusion Criteria

The study was approved by the University Institutional Review Board (protocol code RETRO-PERIMPLANTITIS, 04/07/18). The nature and aim of the study, together with the anonymity in the scientific use of data, were clearly presented in a written informed consent form and signed by every patient. All procedures accorded with the Helsinki Declaration and good clinical practice guidelines for research on human beings. A retrospective evaluation was conducted in a time interval between January and October 2022: patients enrolled for the study had been consecutively referred and treated in 2017 for peri-implantitis on standard, short, and ultra-short locking-taper implants [2,12,40] at the Dental and Maxillo-Facial Surgery University Clinic, and data with 5-year follow-up from the reconstructive treatment were collected. The implant affected by peri-implantitis and consequently treated with reconstructive surgical therapy had to present the following features at the pre-surgical assessment [28]: prosthetic rehabilitation with single crown supporting the implant and without mobility; PPD (peri-implant probing depth) $\geq$ 5 mm, together with positive BOP (bleeding on probing) and/or suppuration, at least at one of the six probed sites; marginal bone loss > 1 mm visible on radiographic examination at least at the mesial or distal site [12]; patient rejecting the option of implant extraction and consequent post-surgical procedures for implant replacement. Patients of the study presented a history of treated periodontitis or were never affected by any form of periodontitis, as previously described [12], and followed regular professional oral hygiene sessions.

Exclusion criteria were as previously described [2,12], plus the following: previous peri-implant surgical interventions; allergy to sulfonates and its derivatives; low-sodium diet, kidney diseases, and sodium bicarbonate flavor intolerance [40].

2.2. Surgical Protocol

All surgical treatments were conducted by a single clinician, as previously described [40]. A complete clinical and radiographic evaluation (dental and periodontal status; panoramic and periapical radiograph; cone beam computed tomography) and basic periodontal treatment were performed before surgery.

A pre-operative medication consisting of 2 g of amoxicillin 875 mg plus clavulanic acid 125 mg (Augmentin®, GSK SpA, Verona, Italy), or 1 g of Clarithromycin 500 mg, (Klacid®, Mylan Srl, Milano, Italy) if allergic to penicillin, was given one hour before surgery. All surgical procedures were performed under local anesthesia, using only Articain 4% with adrenaline 1:100,000 (Citocartin®, Molteni Dental Srl, Milano, Italy). After anesthetizing the site, the single-crown prosthesis was removed, and sulcular incisions were made on the buccal and lingual/palatal sides to preserve soft tissues. A full-thickness flap was raised, and a periosteal incision was performed if a coronal flap advancement was considered appropriate at the time of closure. The eventual supra-crestal exposed area of the implant was smoothed using rotating burs. The surface decontamination procedure [40] consisted of the following three steps, repeated twice: (1) application of a desiccant agent (HYBENX® Oral Tissue Decontaminant, EPIEN Medical, MN, USA) to the defect and to the implant surface, with a 60-s incubation timelapse; (2) thorough irrigation of the defect with saline solution to flush out the desiccant; (3) administration of sodium bicarbonate–based abrasive air powder treatment (AIR-FLOW® CLASSIC sodium bicarbonate powder, Airflow EMS, Nyon, Switzerland) to all contaminated and exposed parts of the implant surface for 60 s. Bone defects were then filled with a composite graft composed of a self-hardening mixture of 50% inorganic bone (Bio-Oss®, Geistlich AG, Wolhusen, Switzerland) and 50% biphasic calcium sulfate (BondBone®, MIS ImplantsTechnologies Ltd., Bar Lev, Israel);

Rifampicin (Rifadin®, Sanofi-Aventis U.S. LCC, Cambridge, MA, USA) was added (1 vial) when appropriate. No membranes were used to cover the graft, and suture was performed with flap mobilization if needed [40]. The original prosthesis or a temporary healing abutment of adequate dimension and with a similar emergence profile was re-inserted to obtain a non-submerged primary tension-free healing. Post-operative care included a 0.12% chlorhexidine rinse (Curasept® ADS 0.12, Curasept SpA, Saronno, Italy) twice daily for 2 weeks, 1 g of antibiotic every 12 h for 7 days, and 800 mg of ibuprofen (Sandoz SpA, Milano, Italy) if needed for pain. Sutures were removed after two weeks. Patients were scheduled to be visited at 1, 3, and 6 months, following regular follow-up every year. A strict maintenance program of oral hygiene sessions every 4 months, together with eventual applications of HYBENX in case of mucositis, was established [12].

2.3. Study Variables and Outcomes

Implant lengths considered in the study were 8.0 and 6.0 mm; implant diameters were 3.5, 4.0, 4.5, and 5.0 mm. Covariates included were sex, age, smoking history, history of periodontitis, ASA status, number of oral hygiene sessions per year, arch involved, tooth site, prosthetic material, CIR, type of peri-implant defect [41–45] (reported as with 1, 2 or 3 remaining walls or circumferential, based on the analysis of X-ray periapical radiographs and intra-operative assessment).

Study outcomes [2,12,40] were: (i) treatment success, (ii) implant loss, (iii) bone level variations, and (iv) soft tissue conditions after 5 years of follow-up, which were assessed according to covariates.

2.3.1. Primary Outcome: Treatment Success

Treatment success [12,41] was defined as the primary outcome according to the following criteria: absence of persistent pain, dysesthesia, or paraesthesia in the implant area; absence of peri-implant infection with bleeding on probing (BoP)/suppuration (SUPP); absence of perceptible mobility of the implant; and finally, absence of persistent peri-implant bone resorption greater than 1 mm during the time interval from surgery to 5-year follow-up. Therefore, once the lost implants are excluded, treatment success can be assessed for survived implants without signs of peri-implantitis after surgery; on the other side, the prevalence of disease recurrence [41] (unsuccessful treatment) can be defined for survived implants with signs of peri-implantitis. In this regard, peri-implantitis was diagnosed [12,42] when an implant had simultaneously one surface with positive BoP or pus on probing, increasing peri-implant probing depths (PPD) compared to previous examinations or PPD $\geq$ 5 mm in the absence of previous examination data, and presence of radiographically detectable bone loss greater than 1 mm when compared with loading measurements. The threshold for bone loss was set at 1 mm in recognition of the fact that in the present study, implant length was highly reduced compared to other longer implant types, for which a threshold of 2 mm can be considered acceptable instead. In the case of 6.0 and 5.0 mm-length implants, a marginal bone loss of 2 mm, representing slightly less than half of the entire implant length, appears to be underestimated after 5 years of follow-up.

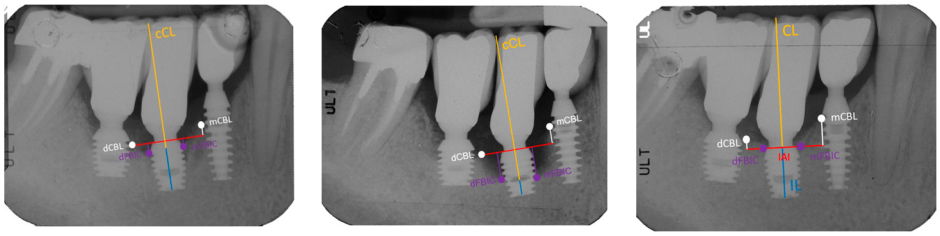
2.3.2. Secondary Outcomes: Implant loss

Implant loss was considered as the implant's state of not being in function at the five-year follow-up evaluation after reconstructive treatment, that is, with symptoms, mobility, radiolucency, or bone loss so severe as to warrant implant removal.

2.3.3. Secondary Outcomes: Clinical and Radiographic Examinations

Clinical and radiographic examinations were assessed at implant loading (Tload), before surgery (Tsurg), 3 years after surgery (T3yrs), and 5 years after surgery (T5yrs). The follow-up evaluations were performed by another operator different from the clinician who performed the surgical phase.

Peri-implant bone levels were measured (Figure 1) using digitally scanned intraoral radiographs, performed with a paralleling technique, using Rinn centering devices (Rinn XCP Posterior Aiming Ring-Yellow, Dentsply, Elgin, IL, USA). Measurements were assessed with the aid of a software program (Rasband, W.S., ImageJ, U. S. National Institutes of Health, Bethesda, Maryland, MD, USA), as previously described [2,12,40]: the analysis included assessment of crestal bone level (CBL, expressed in mm), first bone-to-implant contact (F-BIC, in mm), with their variations ΔCBL (average bone loss) and ΔF-BIC (average apical shift of the "first bone-to-implant contact point" position) [2,12,40].



(**a**) (**b**) (**c**)

Figure 1. Schematic example of the references for peri-implant bone levels measurements at loading (**a**), at surgery time (**b**) and 5 years after surgery (**c**): (IAI) Implant-abutment interface; (mBCL) crestal bone level on the mesial side; (dCBL) crestal bone level on the distal side; (mFBIC) first bone-to-implant contact on the mesial side; (dFBIC) first bone-to-implant contact on the distal side; (CL) crown length; (cCL) clinical crown length; (IL) implant length.

Crestal bone level (CBL) was measured on mesial and distal sides as the linear distance between the implant-abutment interface (IAI) and the highest point of the interproximal bone crest parallel to the lateral sides of the implant body (AC, alveolar crest); first bone-to-implant contact (F-BIC) was defined as the first most coronal bone-to-implant relationship visible at the first line of contact, on both mesial and distal sides [2,12,40].

As described in the literature, implants were divided into two groups on the basis of presenting a crown-to-implant ratio (CIR) less than or greater than two. The crown height was measured on the radiograph immediately after prosthetic loading, from the most occlusal point to the IAI. Anatomical CIR (in which the fulcrum is positioned at the interface between the implant shoulder and the crown-abutment complex) was calculated by dividing the digital length of the crown by the digital length of the implant [2,12,40]. Clinical CIR, where the reference is placed at the most coronal bone-to-implant contact point position [2,13,14], was instead measured at Tsurg, T3yrs, and T5yrs.

Furthermore, Bony Defect Depth (BDD) was recorded at Tsurg, T3yrs, and T5yrs, on mesial and distal sides of each implant as the sum of CBL and F-BIC; for every implant, at each examination interval, an average mesial-distal value was calculated [43,44]. Defect Filling (DEFFILL) was defined as the total percentage of bone filling at T3yrs and T5yrs, that is, the ratio of BDD at T3yrs/T5yrs and BDD at Tsurg (100% of DEFFILL if the ratio was 1, 0% if it was 0).

As previously described [2,12,40], one operator not involved in the surgical phase nor in the follow-up visits completed all measurements on periapical radiographs and was calibrated for adequate intra-/inter-examiner levels of reproducibility in recording the parameters [12].

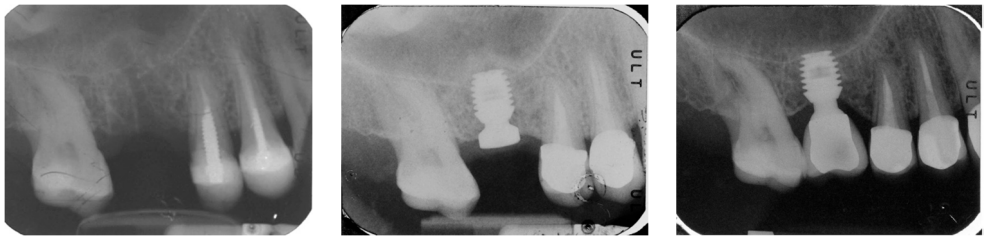
Peri-implant soft tissues were assessed using a periodontal probe (Florida Probe; Florida Probes Company, Gainesville, FL, USA) and applying a force of mild intensity (0.25 N), as previously described [12].

Regarding peri-implant soft tissues, for each implant site, several parameters were assessed at Tsurg, T3yrs, and T5yrs. BoP and SUPP were expressed as percentages. Modified Bleeding Index (mBI) and Modified Plaque Index (mPLI) were used to record the mesial, central, and distal values on the buccal and lingual/palatal sides of each implant. Similarly, PPD (measured as the distance between the vestibular mucosal margin and the bottom

of the pocket) was performed on the same six sites in mm. The amount of keratinized tissue (KT, mm) was assessed by measuring the distance between the zenith of the buccal gingival margin and the mucogingival line. The recession (REC, mm) was assessed as the displacement of the vestibular mucosal margin apically to the margin of the prosthetic suprastructure, and clinical attachment level (CAL, mm) was measured as the distance between the IAI and the bottom of the pocket.

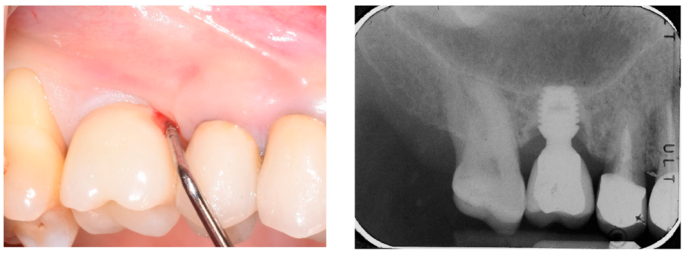
It should be noted that visual signs of inflammation can vary and that peri-implant mucositis can exist around implants with variable levels of bone support [12]. According to the latest updates, peri-implant mucositis was defined as at least one soft-tissue peri-implant surface with positive BoP or pus on probing, PPD $\geq$ 4 mm, and no radiographically detectable bone loss.

Figures 2–9 report a description of a complete clinical and radiographic case with 5-year follow-up: peri-implantitis was detected on a 6 mm-length implant in a 55 years old female patient after 5 years from prosthetic loading; the implant was then treated with the proposed surgical reconstructive protocol and followed for 5 years after treatment.



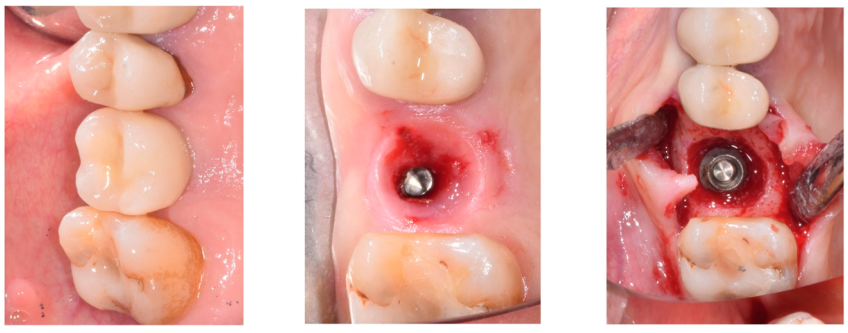
(**a**) (**b**) (**c**)

Figure 2. Radiograph obtained before implant placement (**a**), at time of implant placement (**b**), and at time of loading (**c**) of a short (4.5 × 6 mm) locking-taper implant in 1.6 sites.



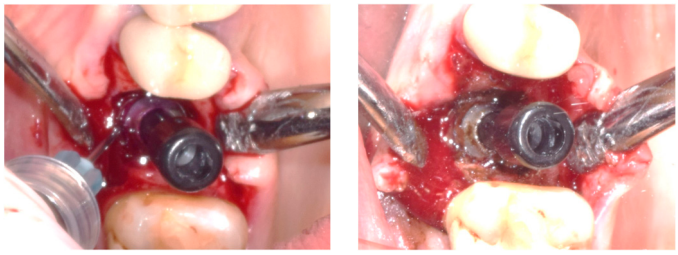
(**a**) (**b**)

Figure 3. Clinical and radiographic signs of peri-implantitis after 5 years from loading. See bleeding on probing with increased PPD (**a**) and apical migration of the F-BIC greater than 1 mm (**b**).



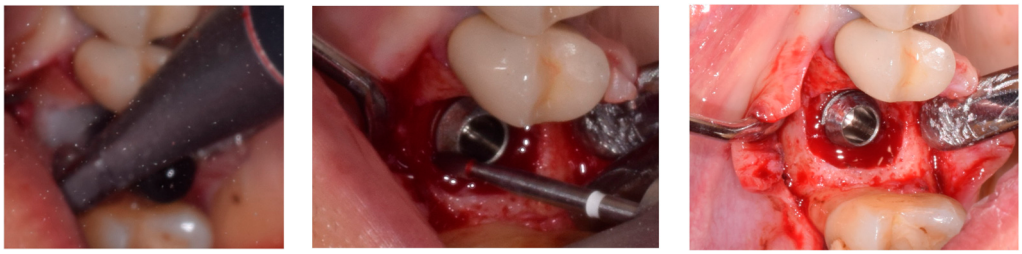
(**a**) (**b**) (**c**)

Figure 4. Clinical photograph of the site the day of peri-implantitis surgical treatment (**a**,**b**), and of the surgical bone defect exposure (**c**).



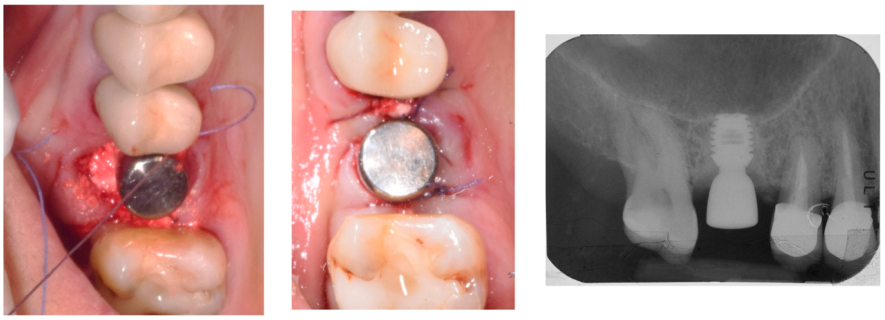
(**a**) (**b**)

Figure 5. Bone defect decontamination with Hybenx desiccant agent (**a**), and intra-operative clinical view after irrigation with saline solution (**b**).



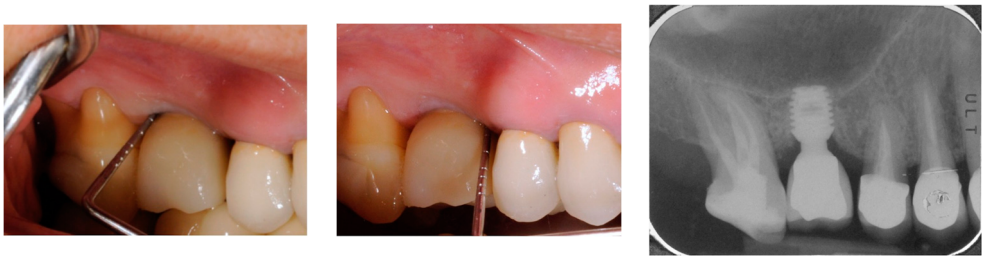
(**a**) (**b**) (**c**)

Figure 6. Air-powder application (**a**), implantoplasty with appropriate burs (**b**), and intra-operative clinical view of the defect (**c**).



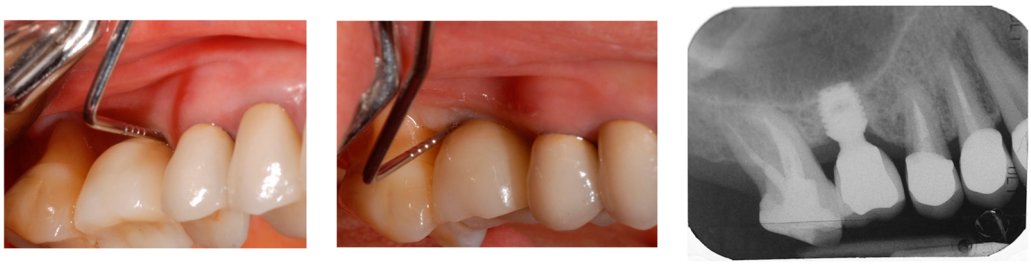
(**a**) (**b**) (**c**)

Figure 7. Intra-operative application of temporary healing abutment and defect filling with bone graft composed of Bio-Oss and Bond-Bone (**a**), clinical view of sutures (**b**), and post-operative radiograph after wound closure (**c**).



(**a**) (**b**) (**c**)

Figure 8. Clinical photographs obtained after 3 years from surgery time: see stable soft tissue conditions with absence of bleeding and decreased PPD (**a**,**b**). A radiograph was obtained after 3 years from surgery time: see bone gain (**c**).



(**a**) (**b**) (**c**)

Figure 9. Clinical photographs obtained after 5 years from surgery time: see stable soft tissue conditions with absence of bleeding and decreased PPD (**a**,**b**). A radiograph was obtained after 5 years from surgery time: see bone gain (**c**).

2.4. Statistical Analysis

All data analysis was carried out using Stata v.13.0 for Macintosh (StataCorp, College Station, TX, USA). The normality assumptions for continuous data were assessed using the Shapiro-Wilk test; mean and standard deviations were reported for normally distributed data, median and interquartile range (iqr) otherwise. Given the non-normal distribution of most of the variables, the comparison between the means at two different times was performed using the Wilcoxon matched-pairs signed-rank test. The comparison between the means of two different groups was performed with the Wilcoxon rank-sum test. The comparison of the means among more than two groups was performed using the Kruskal–Wallis equality-of-populations rank test as appropriate. Bonferroni correction for multiple comparisons was applied.

For categorical data, absolute frequencies, percentages, and 95% confidence intervals were reported. The association between categorical variables was tested with χ^2 test; if any of the expected values was less than 5, a Fisher's exact test was performed. The significance level was set at 0.05. The methodology was reviewed by an independent statistician.

3. Results

3.1. Demographics and Implant Loss

The sample of this study consisted of 20 patients (12 men and 8 women) with 21 locking-taper implants supporting single crowns. Patients enrolled in the study were between 18 and 90 years old. Among patients, 40% were smokers, 50% had an ASA status I, and 55% had a history of periodontal disease. All patients were compliant with the maintenance program, receiving, on average, three professional oral hygiene sessions a year. The mean age at surgery time was 57.69 $\pm$ 9.19 [range 41–75 years].

Among the 21 implants treated in the group of 20 patients, the length of 8 mm was assessed for 9 (42.86%) implants, while the length of 6 mm for 12 (57.14%) implants. Most implants were placed in premolar regions (61.90%) and in the upper maxilla (57.14%). The mean anatomical crown and CIR at loading were, respectively, 12.54 [8.39–16.16] mm and 1.87 [1.04–2.60]. Furthermore, 52.38% of the implants presented an anatomical CIR < 2. According to the defect morphology, one-wall bone defects were identified in 14.29%, two-wall bone defects in 33.33%, three-wall bone defects in 23.81%, and circumferential defects in 28.57% of cases.

Finally, implant loss after 5 years of follow-up was 0% (all implants survived after the treatment at the follow-up). The overall implant distribution, analyzed according to length groups, is presented in Table 1.

3.2. Peri-Implant Bone Levels Variations

Outcomes regarding peri-implant bone levels (CBL, F-BIC, BDD, and DEFFILL) and clinical CIR at each time interval are reported in Table 2.

Table 1. Overall characteristics of 21 implants treated in 20 patients: length-group distribution according to study variables.

	OVERALL		LENGTH-GROUPS						
			6 mm		8 mm		Test Statistic	d.f.	*p* Value
VARIABLE	***n***	**%**	***n***	**%**	***n***	**%**			
SEX									
Male	14	66.67	8	66.67	6	66.67	$\chi^2 = 0.001$	1	0.67
Female	7	33.33	4	33.33	3	33.33			
SMOKING									
No	12	57.14	7	58.33	5	55.56	$\chi^2 = 0.01$	1	0.62
Yes	9	42.86	5	41.67	4	44.44			
ASA STATUS									
I	11	52.38	7	58.33	4	44.44	$\chi^2 = 0.39$	1	0.42
II	10	47.62	5	41.67	5	55.56			
PERIO HISTORY									
No	8	38.1	5	41.67	3	33.33	$\chi^2 = 0.15$	1	0.52
Yes	13	61.9	7	58.33	6	66.67			
ARCH									
Maxilla	12	57.14	6	50	6	66.67	$\chi^2 = 0.58$	1	0.37
Mandible	9	42.86	6	50	3	33.33			
TYPE OF TOOTH									
Incisor	2	9.52	0	0	2	22.22			
Premolar	13	61.9	7	58.33	6	66.67	$\chi^2 = 4.40$	2	0.12
Molar	6	28.57	5	41.67	1	11.11			
IMPLANT DIAMETER									
3.5 mm	1	4.76	0	0	1	11.11			
4 mm	8	38.1	5	41.67	3	33.33	$\chi^2 = 3.07$	3	0.45
4.5 mm	7	33.33	3	25	4	44.44			
5 mm	5	23.81	4	33.33	1	11.11			
CROWN									
Resin	3	14.29	2	16.67	1	11.11	$\chi^2 = 0.12$	1	0.61
Porcelain	18	85.71	10	83.33	8	88.89			
TYPE OF DEFECT									
1-wall	3	14.29	1	8.33	2	22.22			
2-walls	7	33.33	4	33.33	3	33.33	$\chi^2 = 0.93$	3	0.92
3-walls	5	23.81	3	25	2	22.22			
circumferential	6	28.57	4	33.33	2	22.22			

Values are presented as *n* (%); d.f. = degrees of freedom.

Table 2. Overall variations of bone levels and CIR between Tload and Tsurg; between Tsurg and T3yrs; and between T3rs and T5yrs.

Variable/	CBL	F-BIC	BDD	DEFFILL	CIR
Examination Time					
Tload	1.37 [0.92; 1.73]	0.03 [0.01; 0.06]			1.86 [1.04; 2.6]
Tsurg	0.66 [0.19; 1.07]	2.49 [1.05; 4.13]	3.16 [2.53; 3.78]		3.57 [2.05; 7.72]
test statistic	Z = 0.97	Z = 0.47			Z = −4.01
p value	0.0003	0.0003			0.0003
T3yrs	0.28 [−0.5; 0.85]	0.73 [0.1; 2.43]	1.01 [0.85; 1.27]	33.91 [26.48; 46.77]	2.21 [1.47; 3.12]
test statistic	Z = 1.92	Z = −4.01	Z = 4.01		Z = 4.01
p value	0.18	0.0003	0.0002		0.0003
T5yrs	0.36 [−0.43; 0.96]	0.63 [0.05; 2.26]	1.00 [0.56; 1.45]	32.89 [18.73; 44.1]	2.15 [1.43; 3.26]
test statistic	Z = 0.08	Z = −0.75	Z = 0.57	Z = 0.1	Z = 0.78
p value	0.93	0.45	0.56	0.12	0.43

CBL (crestal bone level), F-BIC (first bone-to-implant contact point), BDD (bony defect depth), DEFFILL (defect filling), and anatomical/clinical CIR (crown-to-implant ratio). At each time interval, values for CBL, F-BIC, BDD, and CIR are presented in mm as: median [iqr, interquartile range], where iqr is presented as [p25 (25th percentile); p75 (75th percentile)]; values for DEFFILL are presented in % as median [iqr]. The comparison between the means at two different times was performed using the Wilcoxon matched-pairs signed-rank test; Bonferroni correction for multiple comparisons was also applied.

Statistically significant differences were found for F-BIC, BDD, and CIR between Tsurg and T3yrs, while the same variations remained stable, without significant changes, between T3yrs and T5yrs. Furthermore, mean ΔCBL and mean ΔF-BIC between Tsurg and T5yrs were, respectively 0.30 ± 0.83 mm and 1.86 ± 0.61 mm. Results concerning CBL, F-BIC, BDD, DEFFILL, and CIR between implant length groups are reported (see Table 3).

Table 3. Comparison of BDD, DEFFILL, and CIR, at each time interval, between implant length-groups.

VARIABLE	LENGTH-GROUPS		Test Statistic	*p* Value
	6 mm	8 mm		
BDD Tsurg	2.92 [2.48; 3.46]	3.49 [2.91; 4.13]	Z = −1.35	0.17
BDD T3yrs	1.06 [0.87; 1.51]	0.96 [0.45; 1.27]	Z = 0.1	0.91
BDD T5yrs	1.13 [0.69; 1.52]	0.82 [0.35; 1.35]	Z = 1.42	0.15
DEFFILL T3yrs	39.85 [25.6; 58.78]	25.98 [23.48; 35.97]	Z = 1.35	0.17
DEFFILL T5yrs	40.77 [20.04; 55.16]	22.37 [15.24; 31.5]	Z = 2.06	0.03
CIR				
Tload	2.13 [1.61; 2.6]	1.49 [1.04; 1.8]	Z = 0.99	0.31
Tsurg	4.05 [2.66; 7.72]	2.92 [2.05; 4.28]	Z = −1.27	0.2
T3yrs	2.44 [1.74; 3.12]	1.91 [1.47; 2.67]	Z = −0.82	0.41
T5yrs	2.36 [1.7; 3.26]	1.87 [1.43; 2.38]	Z = −1.49	0.13

Values for BDD and CIR are presented in mm as: median [iqr, interquartile range], where iqr is presented as [p25 (25th percentile); p75 (75th percentile)]; values for DEFFILL are presented in % as median [iqr]. The comparison between the means of two different groups was performed using the Wilcoxon rank-sum test.

Results concerning CBL, F-BIC, BDD, DEFFILL, and CIR between the type of defect groups are reported (see Table 4).

Table 4. Comparison of BDD, DEFFILL, and CIR, at each time interval, between type of defect groups.

VARIABLE	DEFECT TYPE-GROUPS				Test Statistic	d.f.	*p* Value
	1-Wall	2-Walls	3-Walls	Circumferential			
BDD Tsurg	2.27 [1.48; 2.91]	2.98 [2.03; 4.03]	3.40 [2.56; 3.78]	3.62 [3.22; 3.95]	$\chi^2 = 4.49$	3	0.21
BDD T3yrs	1.19 [0.45; 1.97]	0.62 [0.04; 1.08]	1.22 [0.85; 2.03]	1.22 [0.9; 1.61]	$\chi^2 = 2.99$	3	0.39
BDD T5yrs	1.06 [0.3; 1.54]	0.52 [0.35; 0.82]	1.46 [1.02; 1.75]	1.13 [0.74; 1.45]	$\chi^2 = 8.49$	3	0.07
DEFFILL T3yrs	50.65 [30.4; 81.23]	23.15 [10.96; 39.02]	37.86 [33.2; 48.71]	34.79 [24.29; 46.77]	$\chi^2 = 2.95$	3	0.39
DEFFILL T5yrs	43.36 [20.27; 63.5]	18.95 [8.46; 27.35]	46.79 [33.3; 69.23]	32.33 [18.73; 42.54]	$\chi^2 = 5.67$	3	0.12
CIR							
Tload	2.15 [1.79; 1.64]	2.13 [1.63; 2.05]	1.52 [0.98; 1.82]	1.43 [1.37; 2.14]	$\chi^2 = 5.87$	3	0.92
Tsurg	4.02 [3.91; 5.07]	4.03 [3.57; 4.98]	3.75 [3.26; 4.62]	3.07 [2.75; 3.93]	$\chi^2 = 4.21$	3	0.75
T3yrs	2.47 [1.98; 3.25]	2.06 [1.84; 3.24]	2.38 [2.04; 3.51]	2.09 [1.89; 2.52]	$\chi^2 = 3.92$	3	0.28
T5yrs	2.25 [2.17; 2.99]	2.02 [1.96; 3.01]	2.16 [2.08; 3.2]	1.98 [0.94; 1.66]	$\chi^2 = 2.56$	3	0.18

Values for BDD and CIR are presented in mm as: median [iqr, interquartile range], where iqr is presented as [p25 (25th percentile); p75 (75th percentile)]; values for DEFFILL are presented in % as median [iqr]; d.f. = degrees of freedom. The comparison of the means among more than two groups was done using the Kruskal–Wallis equality-of-populations rank test.

3.3. Soft Tissues Conditions

Soft tissue outcomes were stable at T3yrs and T5yrs (see Table 5), demonstrating the same trend of bone level variations, thus confirming the stability of conditions 3 years and 5 years after surgery, with no significant variations between follow-up time intervals.

Table 5. Overall variations of soft tissue conditions between Tsurg and T3yrs and between T3rs and T5yrs.

VARIABLE	Tsurg	T3yrs	Test Statistic	*p* Value	T5yrs	Test Statistic	*p* Value
PPD	8.14 [7; 9]	3.66 [3; 4]	Z = 4.03	0.0003	3.71 [3; 5]	Z = −0.72	0.46
mBI	2.47 [2; 3]	0.23 [0; 1]	Z = 4.07	0.0003	0.33 [0; 1]	Z = −0.94	0.34
mPLI	1.85 [1; 2]	0.47 [0; 1]	Z = 3.97	0.0003	0.46 [0; 1]	Z = −0.51	0.6
REC	0.09 [0; 1]	1.04 [1; 2]	Z = −3.76	0.0006	1.14 [1; 2]	Z = −1.41	0.45
KT	3.19 [3; 4]	2.47 [2; 3]	Z = 3.71	0.0006	2.38 [2; 3]	Z = 1.41	0.45
CAL	8.23 [7; 9]	4.70 [2; 5]	Z = 4.02	0.0003	4.85 [2; 5]	Z = 0.93	0.79

PPD (probing pocket depth), mBI (modified bleeding index), mPLI (modified plaque index), REC (recession), KT (keratinized tissue), and CAL (clinical attachment level). At each time interval, values for PPD, KT, REC, and CAL are presented in mm as: median [iqr, interquartile range], where iqr is presented as [p25 (25th percentile); p75 (75th percentile)]; values for mBI and mPLI are presented as median [iqr]. The comparison between the means at two different times was performed using the Wilcoxon matched-pairs signed-rank test; Bonferroni correction for multiple comparisons was also applied.

Prevalence of BOP decreased from 100% (all implants) at Tsurg to 19.05% (4 implants) at T3yrs ($p = 0.0003$), remaining stable at T5yrs ($p = 0.31$). Prevalence of SUPP decreased from 38.1% (8 implants) at Tsurg to 9.52% (2 implants) at T3yrs ($p = 0.03$), remaining stable at T5yrs ($p = 0.99$).

Furthermore, no significant differences were found between length groups concerning variations of variables related to soft tissue conditions over time (see Table 6).

Table 6. Overall variations of soft tissue conditions between Tsurg, T3yrs, and T5yrs, according to length-groups.

VARIABLE	LENGTH GROUPS		Test Statistic	*p* Value
	6 mm	8 mm		
PPD				
Tsurg	7.83 [7; 9]	8.55 [7; 9]		
T3yrs	3.41 [3; 4]	4 [3; 4]		
T5yrs	3.41 [3; 5]	4.11 [3; 5]		
Δ Tsurg-T5yrs	4.41 [4; 5]	4.44 [4; 5]	Z = −0.28	0.97
mBI				
Tsurg	2.50 [2; 3]	2.44 [2; 3]		
T3yrs	0.16 [0; 1]	0.33 [0; 1]		
T5yrs	0.25 [0; 1]	0.44 [0; 1]		
Δ Tsurg-T5yrs	2.25 [2; 3]	2.00 [2; 3]	Z = −0.56	0.3
mPLI				
Tsurg	1.75 [1; 2]	2.00 [1; 2]		
T3yrs	0.50 [0; 1]	0.44 [0; 1]		
T5yrs	0.41 [0; 1]	0.55 [0; 1]		
Δ Tsurg-T5yrs	1.33 [1; 2]	1.44 [1; 2]	Z = −1.05	0.84
REC				
Tsurg	0.16 [0; 1]	0.01 [0; 1]		
T3yrs	1.16 [1; 2]	0.88 [1; 2]		
T5yrs	1.25 [1; 2]	1.00 [1; 2]		
Δ Tsurg-T5yrs	(−)1.08 [1; 2]	(−)1.00 [1; 2]	Z = −0.36	0.65

Table 6. *Cont.*

VARIABLE	LENGTH GROUPS		Test Statistic	*p* Value
	6 mm	8 mm		
KT				
Tsurg	3.08 [3; 4]	3.33 [3; 4]		
T3yrs	2.25 [2; 3]	2.77 [2; 3]		
T5yrs	2.16 [2; 3]	2.66 [2; 3]		
Δ Tsurg-T5yrs	0.91 [0; 1]	0.66 [0; 1]	Z = −1.82	0.28
CAL				
Tsurg	8.47 [7; 9]	8.15 [7; 9]		
T3yrs	4.56 [2; 5]	4.77 [2; 5]		
T5yrs	4.74 [2; 5]	4.86 [2; 5]		
Δ Tsurg-T5yrs	3.73 [2; 5]	3.29 [2; 5]	Z = −0.92	0.97

PPD, mBI, mPLI, REC, KT and CAL. At each time interval, values for PPD, KT, REC, and CAL are presented in mm as: median [iqr, interquartile range], where iqr is presented as [p25 (25th percentile); p75 (75th percentile)]; values for mBI and mPLI are presented as median [iqr]. The comparison between the mean variations in two different times (Δ Tsurg-T5yrs) of two different groups was performed using the Wilcoxon rank-sum test.

Prevalence of BOP and SUPP were both equally distributed, respectively, in 6 mm and 8 mm length groups at T3yrs and also at T5yrs, without differences between groups ($p = 0.07$ and $p = 0.32$).

3.4. Treatment Success and Disease Recurrence

During the time interval from Tsurg to T3yrs, 3 implants (one 6 mm and two 8 mm-length) in 3 patients experienced loss of supporting bone greater than 1 mm. Finally, after 5 years, 4 implants (one 6 mm and three 8 mm-length) in 4 patients exhibited peri-implantitis, for an overall implant-based treatment success of 80.95% (17/21). No significant associations ($p < 0.05$) were found between covariates and treatment success/disease recurrence (see Table 7).

Table 7. Analysis of 5-year treatment success on 21 treated implants according to included study covariates.

	Disease Recurrence		Treatment Success				
VARIABLE	***n***	**%**	***n***	**%**	**Test Statistic**	**d.f.**	***p* Value**
SEX							
Male	2	14.29	12	87.51	$\chi^2 = 0.61$	1	0.4
Female	2	28.57	5	71.43			
SMOKING							
No	3	25	9	75	$\chi^2 = 0.64$	1	0.41
Yes	1	11.11	8	88.89			
ASA STATUS							
I	2	18.18	9	81.82	$\chi^2 = 0.01$	1	0.66
II	2	20	8	80			
PERIO HISTORY							
No	1	12.5	7	87.5	$\chi^2 = 0.35$	1	0.5
Yes	3	23.08	10	76.92			
ARCH							
Maxilla	2	16.67	10	83.33	$\chi^2 = 0.1$	1	0.58
Mandible	2	22.22	7	77.78			
TYPE OF TOOTH							
Incisor	0	0	2	100			
Premolar	2	15.38	11	84.62	$\chi^2 = 1.37$	2	0.71
Molar	2	33.33	4	66.67			
IMPLANT LENGTH							
6 mm	1	8.33	11	91.67	$\chi^2 = 2.08$	1	0.18
8 mm	3	33.33	6	66.67			
IMPLANT DIAMETER							
3.5 mm	0	0	1	100			
4 mm	1	12.5	7	87.5	$\chi^2 = 0.87$	3	0.83
4.5 mm	2	28.57	5	71.43			
5 mm	1	20	4	80			

Table 7. *Cont.*

	Disease Recurrence		Treatment Success				
VARIABLE	***n***	**%**	***n***	**%**	**Test Statistic**	**d.f.**	***p* Value**
CROWN							
Resin	0	0	3	100	$\chi^2 = 0.82$	1	0.51
Porcelain	4	22.22	14	77.78			
CIR							
<2	3	27.27	8	72.73	$\chi^2 = 1.01$	1	0.33
>2	1	10	9	90			
TYPE OF DEFECT							
1-wall	1	33.33	2	66.67			
2-walls	3	42.86	4	57.14	$\chi^2 = 5.55$	3	0.13
3-walls	0	0	5	100			
circumferential	0	0	6	100			

Values are presented as *n* (%); d.f. = degrees of freedom.

4. Discussion

To the best of our knowledge, this is the first study presenting clinical and radiographic outcomes on standard and short implants [40], supporting single crowns with disproportionate CIRs, treated for peri-implantitis, and followed with a regular and strict maintenance protocol for 5 years. Twenty-one locking-taper implants with single crowns were treated with a reconstructive surgical protocol consisting of access flap surgery, concomitant chemical and mechanical decontamination of the implant surface, and bone grafting (using a self-hardening mixture of bone substitutes and biphasic calcium sulfate), without the use of membrane and allowing a transgingival healing.

Regarding the primary outcome, the proposed reconstructive protocol proved to be successful in arresting the disease progression: all clinical and radiographic parameters significantly improved from surgery to 3 years, with a small prevalence of disease recurrence between 3-year and 5-year follow-up. After 5 years, 4 implants (one 6 mm and three 8 mm-length) in 4 patients exhibited peri-implantitis recurrence, for an overall implant-based treatment success of 80.95% (17/21). Implant loss was 0%. Soft tissue outcomes were stable at T3yrs and T5yrs, demonstrating the same trend of bone level variations, thus confirming stability of conditions 3 years and 5 years after surgery, with no significant variations between follow-up time intervals.

Current literature presents a large amount of data stating that implants may be affected by peri-implantitis, and a fair number of studies discussed the possibilities of reconstructive treatments on standard dental implants [26–34,45]; on the other hand, there is a lack of reliable evidence for effective and codified protocols for the treatment of peri-implantitis around short implants, especially when supporting single crowns. In this proposal, it was recently demonstrated that short and ultra-short implants locking taper implants with a plateau design are not immune to peri-implantitis [12], which represents a critical issue considering that moderate bone loss could be definitively harmful around an implant with reduced length. In the present study, the root-form implant macro-design [2,12], presenting plateaus and healing chambers allowing for a unique Haversian bone formation and remodeling, seems to provide significantly increased mechanical properties to the residual intra-bony component of the affected implant [12], permitting an effective transference of the loading forces to the bone, together with adequate implant stability during the healing phase, sufficient to resist the overload.

It may be queried if a few plateaus still osteo-integrated may allow for sufficient implant stability even under the influence of highly disproportionate CIRs associated with peri-implantitis: at this proposal, it is reported that, with this design, adjacent bone is hardly loaded at levels that could exceed the minimum effective strain necessary for bone modeling and remodeling during the early stages of bone regeneration [46–49]. It is worth noticing that even though 6 mm-length implants had to deal with significantly greater clinical CIR, they did not underperform, showing adequate treatment success. For this

reason, authors postulate that implant length, when the plateau-design implant is still osteo-integrated, does not affect treatment possibilities. However, only the histological examination could confirm the growth of new bone in direct contact with the implant surface or the peri-implant defect space filled only by the graft [50–52].

Final outcomes in reconstructive surgery are usually influenced by two critical phases: the implant surface decontamination and the peri-implant defect filling [53]. The rationale for using, in the described protocol, a desiccant solution in association with air-powder abrasion is that it quickly and completely denatures organic molecular biofilm components, weakening its molecular attachment mechanisms and enabling an easier and more effective mechanical debridement [54–56]. In addition, as experimental studies on animals reported re-osseointegration after decontamination of the implant surface with abrasive powder, sandblasting systems using different abrasive particles were proposed for the surgical treatment of peri-implantitis [57]. Furthermore, cell proliferation was shown to be greater when using a bicarbonate jet rather than using a laser for decontamination [58]. The combined action of the topical desiccant agent and air powder abrasion resulted to be effective in disinfecting the implant surface and allowing proper reconstruction: PPD of 8.14 mm was significantly reduced to 3.71 mm after 3 years from surgery, without any significant differences between length groups in disease recurrence after 5 years. These results are in line with other studies which found comparable values [59–63]. Moreover, a systematic review was performed to identify the most effective and predictable option for the surgical reconstructive treatment of peri-implantitis, and it stated that a PPD reduction of 2.78 mm is generally to be expected [28].

After decontamination, a self-hardening graft, composed of a mixture of deproteinized bovine bone and biphasic calcium sulfate, was used as filling material: while the first [50,52,64] acts as a long-term space maintainer, the second [51,65] is a short-term maintainer, which completely degrades in strict relation to the bone formation rate (4–10 weeks); at the same time, calcium sulfate confers to the composite bone graft the ability to harden and to remain in place even in the presence of blood and saliva [66]. All surgical procedures described in the protocol and subsequent healing phase occurred without complications and with minimal post-operative discomfort: a mean radiographic defect filling of 32.89% was found after 5 years from surgery, with a relevant radiographic bone gain (ΔF-BIC) of 1.86 mm, without significant differences between length-groups. Even if in the case of these locking-taper implants treated for peri-implantitis, bone levels assessed at T5yrs did not reach values comparable with loading time, but at least close to the IAC reference, outcomes can be considered satisfactory in terms of bone gain. Furthermore, radiographic findings highlighted the potential benefits of the composite graft used even in the presence of oral fluids and to maintain itself even in non-contentive defects [63,64]. These outcomes resulted consistent with data from systematic reviews on standard implants, which reported an amount of radiographic bone filling varying from 1.46 to 3.30 mm after 3 years [59]: a mean value of 2 mm may be generally expected when bone substitutes are used for the reconstruction of peri-implant intra-bony defects [37].

It should be emphasized that the composite bone graft was applied in the absence of a membrane. Membranes are currently applied on top of reconstructive material to comply with the principle of "compartmentalization" [67–70], based on the concept that it prevents soft tissue ingrowth into a defect region, allows the angiogenic and osteogenic cells to migrate into the blood clot, and as a stabilizer for the material in case of "non-contenitive" defects [71]. However, their use was recently discussed because of reports of post-surgical exposure, resulting in increased morbidity and a higher prevalence of residual soft tissue inflammation. Some authors report an absence of complications during the healing phase in patients treated with only bone grafts, compared with a prevalence between 55% and 60% in patients treated with a membrane [39]. Other authors reported a prevalence of membrane exposure of 90.2%, with a peak between the second (43.8%) and the seventh (34.4%) week of healing [72]. Despite recent encouraging outcomes demonstrated by bioresorbable membranes based on platelet concentrates in stimulating angiogenesis and

cellular proliferation, no clear evidence was found to support the benefits of specific barrier membranes (e.g., growth factor versus collagen membrane) in the reconstructive surgical treatment of peri-implantitis [70].

In light of these considerations and considering that several RCTs performed in the presence/absence of barrier membranes [38,72] did not report improved outcomes in terms of implant prognosis for procedures using membranes, their use was avoided, choosing for a transgingival healing around the original prosthesis or using a healing cup of appropriate dimension.

Short and ultrashort locking-taper implants are mainly positioned in posterior atrophic areas, where alveolar ridges are usually wider, and defects are circumferential and contentive. Being these implants positioned 2 mm sub-crestal [2,12], in case of peri-implantitis, bone defects filling after surgery do not usually result in screws exposure at follow-ups, which instead frequently characterizes other implant types with juxta-crestal placement. Regarding overall bone level variations analyzed in the study, statistically significant differences were found for F-BIC, BDD, and CIR between Tsurg and T3yrs, while the same variations demonstrated to remain stable, without significant changes, between T3yrs and T5yrs: mean ΔCBL and mean ΔF-BIC between Tsurg and T5yrs were, respectively, 0.30 ± 0.83 mm and 1.86 ± 0.61 mm. We can assume this trend as clinically relevant in terms of the stability of results obtained with the proposed reconstructive protocol after 3 years and 5 years. Moreover, despite histo-pathological examination [73] was not performed, peri-implant defects were identified in terms of residual walls number: no significantly greater bone gain and defect filling was found in contentive (3-walls o circumferential) defects, compared to non-contentive (1–2 walls) defects, both in 6 mm and 8 mm-length groups, at any time interval.

The importance of optimal plaque control and a strict maintenance program, observed by all patients in the present study, was widely described in the literature as a gold standard for preventing biological complications [35,74–76]. Despite a great decrease from Tsurg to T3yrs and T5yrs, percentages of BoP and suppuration were not entirely solved. In this proposal, it may be stated that complete and resolutive healing of inflamed peri-implant tissues is not an easily achievable goal, even if our results seem to be favorably comparable with other clinical studies [77,78] and recent systematic reviews [38,59], which reported BOP reductions comprehended between 40% and 60% after reconstructive treatments with bovine xenografts in sites affected by peri-implantitis.

In this proposal, it should be underlined that compliance in supportive therapy is a difficult goal to achieve, generally reported as unsatisfactory by several authors [79,80]. Even if uncommon, all patients in the present study strictly followed all recall appointments, and no drop-out was registered after 5 years of surgical treatment. As the setting for the study was a University Hospital Dental Clinic, the authors suggest that patients demonstrated to be extremely compliant in follow-ups not for their own predisposition but because they were strongly motivated and for extreme efforts and dedication by the structure. Moreover, this study presented a limited number of 20 patients, allowing easy strategies for motivation. Plus, half of the patients with a history of periodontal disease were probably deeply aware of the importance of regular maintenance.

Several authors reported different treatment goals for assessing treatment success in reconstructive treatments, and outcomes in this regard widely differ in the literature [81,82]. In the present study, where successful treatment was defined as the absence of radiographic evidence of bone loss greater than 1 mm with the deepest probing depth inferior to 5 mm, treatment success was 85.71% at T3yrs and 80.95% at T5yrs. Other studies with similar endpoints on standard implants registered even lower success rates [43,60,61,83]. From a clinical point of view, despite no significant associations ($p < 0.05$) being found between covariates and treatment success, predictable results reported in this study may be associated with an effective reduction of BoP, mBI, and mPLI scores in mid-term (3 years) as well as in long-term (5 years), even if a complete resolution of the inflammation was not finally achieved. Another factor that could have positively contributed to high treatment success is the amount of KT, evaluated as a mean of 2.38 mm, a value

considered as a protective factor for further recessions and bone loss in case of impaired oral hygiene procedures, soft tissue damage, plaque accumulation, and bleeding [84,85].

Finally, limitations of this retrospective investigation consist of small sample size, radiographic evaluation of defects using 2D peri-apical radiographs, absence of histological analysis, and no comparison with other graft materials.

Potential Shortcomings of Peri-Implantitis Diagnosis

Limitations of this study, concerning both its retrospective nature and a limited number of patients, encourage larger investigations, preferably based on a prospective approach: a control group could be represented, in this case, by untreated implants. The option to hypothetically compare two groups, one surgically treated and another not treated with a surgical approach, could be warranted by the evidence that bone loss presents a non-linear progression and increasing rate of loss over time [86].

Firstly, a recent analysis [87] determined marginal bone loss in the context of aseptic mechanisms involving the osteoimmunological response, outlining it as a condition rather than a disease. In this proposal, it seems that biofilm related to inflammation makes a secondary contribution in affecting implant stability, which is otherwise primarily connected to immune system reaction, and this issue makes peri-implant diagnosis difficult to assess.

On the other hand, the "pilot" experience here reported is based on clinical findings of a reconstructive protocol aimed, in the context of daily routine practice, to maintain peri-implant health around a specific type of implant, for which a minimum excessive marginal bone loss, occurred for any reason, can represent a fast non-reversible process able to lead to implant loss. The threshold for critical bone loss was here set at 1 mm in recognition of the fact that in the present study implant length was highly reduced compared to other longer implant types, so the marginal bone loss has to be considered according to the following features: (i) a short/ultrashort implant (in this case 8 and 6 mm length); (ii) rehabilitated with single crown and (iii) with disproportionate high crown-to-implant ratios (CIRs).

Secondly, clinical indexes of BOP, PPD, and mPLI were registered in the context of a rigorous methodology for follow-up. Even if several authors stated the risk of over-diagnosis and consequent over-treatment in focusing on these indexes [88,89], inflammation appears to be correlated at least to mucositis. In light of this consideration, the inclusion of signs of bleeding and probing in peri-implantitis diagnosis is important not only to align with established official guidelines but also to consider that the persistence of inflammation in the long term could represent a predisposing factor for future bone loss. The importance of optimal control of inflammatory signs, described in the literature as a gold standard for preventing biological complications, is thus essential in achieving treatment success.

Thirdly, despite studies in literature declaring that implants characterized by "progressive bone loss" if treated (oral hygienist and/or surgery) did not perform better than untreated patients with regard to bone loss or implant failure [90] or even resulted in more prevalence of failure compared to doing nothing at all [91], other authors suggested the importance of controlling combined factors (implant characteristics, clinical handling, patient characteristics) in obtaining long-term good clinical results [92].

In this proposal, longer implants considered by the abovementioned investigations [90,91] did not present the issue of disproportionate CIRs typical of short-length single-crown implants. Nevertheless, the specific feature of root-form implant macro-design (which allows significantly increased mechanical properties to the residual intra-bony component of the affected implant) represents an advantage in terms of stability of bone levels after 5 years of follow-up, as the bone loss was limited than expected, also for patients with a history of periodontal disease.

To sum up, the authors believe that a proper clinical approach is based on clinical considerations for maintaining the in-place implant, if possible, meeting patients' expectations in terms of avoiding its removal and proposing an alternative non-invasive procedure.

5. Conclusions

Within the limitations of this retrospective study, it can be suggested that the proposed surgical protocol for the treatment of peri-implant bone defects is demonstrated to maintain the function of all implants. Promising 5-year clinical and radiographic outcomes, assessed during the maintenance program after surgery, showed that implant length does not affect treatment possibilities if the implant stability is preserved. Moreover, accurate disinfection and grafting procedures effectively reduced patient morbidity via the avoidance of barrier membranes. These results encourage further clinical confirmations with larger samples and longer follow-ups.

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List of Abbreviations

CIR	crown-to-implant ratio
PPD	peri-implant probing depth
BoP	bleeding on probing
Tload	implant loading time
Tsurg	time before surgery
T3yrs	3 years after surgery time
T5yrs	5 years after surgery time
SUPP	suppuration
mBI	Modified Bleeding Index
mPLI	Modified Plaque Index
KT	keratinized tissue
REC	recession of the vestibular mucosal margin
CAL	clinical attachment level
CBL	crestal bone level
F-BIC	first bone-to-implant contact
ΔCBL	average bone loss
ΔF-BIC	average apical shift of the “first bone-to-implant contact point” position
AC	alveolar crest
IAI	implant-abutment interface
BDD	Bony Defect Depth
DEFFILL	Defect Filling

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