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ORIGINAL ARTICLE

Short and ultra-short (<6-mm) locking-taper implants supporting single crowns in posterior areas (part II): A 5-year retrospective study on periodontally healthy patients and patients with a history of periodontitis

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Abstract

Background: Short and ultra-short implants implants supporting single crowns seem to demonstrate high percentages of survival and stable marginal bone levels at a mid-term follow-up. Nevertheless, insurgence of peri-implant complications still represents a critical issue, especially for patients with history of periodontitis.

Purpose: The aim of this retrospective study was to evaluate implant survival, marginal bone loss and peri-implant complications in 333 short and ultra-short implants, placed in periodontally healthy patients and patients with a history of periodontitis.

Materials and Methods: Implants were placed in the maxillary and mandibular posterior regions of 142 patients with (PP) and without (NPP) a history of periodontitis. Clinical and radiographic examinations were performed at 5-year recall appointments.

Results: Implants respectively placed in PP and NPP were: 35.68% and 42.50% in 8.0 mm-length group, 33.33% and 36.67% in 6.0 mm-length group, and 30.99% and 20.83% in 5.0 mm-length group. Implant-based survival after 5 years of follow-up was 95.77% for PP and 96.67% for NPP ($p = 0.77$). Regarding crestal bone level variations, average crestal bone loss was statistically different ($p = 0.04$) among PP (0.74 mm) and NPP (0.61 mm). Implants presenting signs of mucositis were 6.86% in PP and 7.76% in NPP ($p = 0.76$). Setting the threshold for excessive bone loss at 1 mm after 60 months, peri-implantitis prevalence was 7.84% in PP and 2.59% in NPP ($p = 0.08$). Overall implant success was 92.16% and 97.41%, respectively, for PP and NPP.

Conclusions: Under strict maintenance program, five-year outcomes suggest that short and ultra-short locking-taper implants can be successfully restored with single crowns in the posterior jaws both in PP and NPP.

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KEYWORDS
mucositis, peri-implantitis, periodontitis, short, single crown, ultra-short

What is known:

Short (lengths ≥6 mm and ≤8 mm) and ultra-short (<6 mm) implants supporting single crowns seem to demonstrate 3-year and 5-year predictable outcomes in terms of survival and crestal bone levels. Furthermore, non-splinted restorations represent a gold standard in terms of oral hygiene, which is essential for patients following a specific strict maintenance protocol, as the ones treated for periodontitis.

What this study adds:

This retrospective study adds further aspects to recently published promising 3-year and 5-year results, regarding short and ultra-short plateau-design, locking-taper implants, supporting single crowns. In this complementary study, history of periodontitis was the main variable according to which implant survival and peri-implant conditions were analyzed, in the same sample of patients of the recently published 5-year study.

1 | INTRODUCTION

The use of dental implants in supporting prosthetic rehabilitations for partially or totally edentulous patients showed a significant increase over the last decades. Several longitudinal studies[1] reported implant survival percentages ranging from 92.8% to 97.1% over a period up to 10 years, demonstrating that dental implants constitute a valid treatment option for the replacement of missing teeth. At this proposal, favorable results were recently provided for the use of short implants (6 mm-length) as an effective therapy in the rehabilitation of upper maxillary and mandibular jaw atrophies.[2,3] Even if available 5-year studies[4] support the use of these implants as a predictable method only if splinted with other implants, other current investigations propose the possibility of their use as single crown implants,[5–7] which may be suggested as a gold standard in terms of oral hygiene procedures.[8]

Moreover, even if dental implants seem to demonstrate high percentages of survival and stable marginal bone levels at a long-term follow-up, insurgence of peri-implant diseases still represents a critical issue.[9] Clinical signs of peri-implant inflammation around soft tissues (bleeding on probing, erythema, swelling, and/or suppuration), without loss of supporting bone, typically regard the onset of peri-mucositis.[10,11] Once this condition turns to a non-reversible infection, in which periodontal bacteria are involved in massively reducing marginal bone levels, peri-implantitis can be observed. Peri-implantitis implies a non-linear progressive bone destruction, with a faster progression rate compared to periodontitis,[12,13] due to specific microorganisms present at the implant site, host defense and absence of periodontal ligament.[9,14] It is thus essential to establish codified protocols to prevent or efficiently manage the development of peri-implant diseases,[15] as peri-implant inflammation is directly connected with the presence of plaque deposits.[9–11]

At this regard, history of periodontitis is considered a preponderant risk factor, among others, in determining the possible development of severe peri-implant complications.[16] Several reviews and metanalysis[17–19] reveal that patients with a history of periodontitis, over a long term, show higher values of probing pocket depth, greater bone loss and higher prevalence of peri-implantitis compared to periodontally healthy patients. The evidence concerning clinical and radiographic outcomes of short and ultra-short implants placed in patients with treated periodontitis is still scarce and lacking long-term homogeneous follow-ups.[20–23] Furthermore, it is currently highly debated the use of these implants supporting single crowns specifically in this type of patients.[22] Sites with deep pocketing and gingival bleeding typical of periodontitis, once properly treated to achieve a successful resolution of the inflammation, remain however characterized by an unavoidable bone loss,[24] for which reduced-length implants often represent the main option to re-establish a functional fixed rehabilitation. Despite the advantages offered by this solution, strict maintenance protocols need to be established in periodontal patients rehabilitated with implants, to avoid an additional extensive marginal bone loss,[25] that could be definitively harmful in case of a short or ultra-short implant.

Based on the limits of the already published 3-year investigations,[8,22] authors here hypothesized that longer-term assessment is required for a proper clinical evaluation of effective conditions of locking-taper implants rehabilitated with single crowns, especially if placed in patients with history of periodontitis. The aim of this 5-year retrospective study, which adds complementary results to another investigation on the same sample of patients,[23] was to assess implant survival, marginal bone loss and implant success of 333 short and ultra-short implants restored with single crowns in the maxillary and mandibular edentulous posterior regions, respectively, placed in patients with history of periodontitis (PP), and patients without history of periodontitis (NPP). As previously described,[23] a rigorous value of 1 mm was set as threshold for radiographically detectable marginal bone loss, measured during the time interval from loading to 5-year follow-up, and compatible with implant success and absence of signs of peri-implantitis.

2 | MATERIALS AND METHODS

A retrospective study with a 5-year follow-up was conducted in 2020 on patients who had been referred between February 2007 and June 2015, for edentulism (tooth loss caused by trauma, caries or periodontitis) in the posterior areas of maxilla and mandible at the Dental and Maxillo-Facial Surgery Clinic at the University of Verona (Italy). The study was approved by the University Institutional Review Board (Prot. 34 939, CROWNMAXMAND, 30/05/18). 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 Helsinki Declaration and good clinical practice guidelines for research on human beings.[23]

Patients enrolled for the study, which presented the same sample of the recently published 5-year follow-up retrospective study,[23] matched the following inclusion criteria[8,22,23]: aged between 18 and 90 years; having had single-tooth replacement of at least one 8.0, 6.0, or 5.0 mm locking-taper implant supporting a single crown; had reduced alveolar bone height and had no previous consent for bone augmentation procedures; had a history of treated periodontitis, or were never affected by any form of periodontitis; and who were compliant with a regular maintenance program (professional oral hygiene sessions every 4 months).

Patients with a history of treated periodontitis were characterized by previously assessed forms of periodontitis, corresponding to stage I, II or III, and grade A or B, according to the latest updates on classification of periodontal and peri-implant diseases.[10,11,23,24] These patients were subjects following a regular maintenance program on a reduced periodontium every 3 months to ensure gingival health at the time of implant placement. On the other hand, periodontally healthy patients were subjects never affected by any form of periodontitis.[22,23]

Exclusion criteria for the study were[8,22,23]: presence of active infection at an implant site; ASA status III, IV,V, and VI (according to the American Society of Anesthesiologists' classification), that is, severe systemic diseases or substantive functional limitations which contraindicated implant surgery (such as drug or alcohol abuse, uncontrolled diabetes mellitus, immunosuppression or immunodepression, severe autoimmune diseases, treatment or past treatment with intravenous amino-bisphosphonates for metastatic bone diseases, radiotherapy to head or neck within 2 years prior to treatment, history of malignancy or chemotherapy within the previous year, treatment with oral amino-bisphosphonates for more than 3 years, morbid obesity, active hepatitis, severe renal disease, severe cardiovascular conditions, recent history of myocardial infarction (MI) or transient ischemic attack (TIA)); untreated periodontitis; poor oral hygiene and motivation; current pregnancy or lactation; heavy smoking (more than 25 cigarettes per day); severe clenching or bruxism.

All surgical treatments were conducted by a single clinician, as previously described[8,22,23] [see Appendix]. Clinical and radiographic examinations[8,22,23] were performed during the follow-up 5 years from loading time, one time per year at regular intervals. The post-surgery evaluations and the follow-up evaluations [see Appendix] were performed by two other operators both of whom were different from the clinician who performed the surgical phase.

Implant lengths considered in the study were 8.0, 6.0, and 5.0 mm; implant diameters were 3, 3.5, 4.0, 4.5, 5.0, 6.0 and 6.5 mm. Covariates included were: sex, age, smoking history, history of periodontitis,[10,11,24] ASA status, number of oral hygiene sessions per year, use of interproximal oral hygiene devices, arch involved, tooth site, prosthetic material, crown-to-implant ratio (CIR).[8,22,23]

A descriptive analysis was conducted between loading time and the 5-year follow-up time, according to covariates. This included assessment of crestal bone level (CBL, average bone level around implants at mesial and distal sides, expressed in mm), first bone-to-implant contact (F-BIC, in mm)[8,22,23,26] with their variations ΔCBL (average bone loss) and ΔF-BIC (average apical shift of the "first bone-to-implant contact point" position) [see Appendix].

Peri-implant soft tissues were assessed using a periodontal probe (Florida Probe; Florida Probes Company) and applying a force of mild intensity (0.25 N). For each implant site, four parameters were assessed. The Modified Bleeding Index (mBI), and the Modified Plaque Index (mPLI), as reported in the literature by Mombelli,[27] were used to record the appropriate values for the mesial, central, and distal on the buccal and lingual/palatal sides of each implant. Similarly, the peri-implant probing depths (PPD) were performed on the same six sites. The amount of keratinized tissue (KT) was assessed by measuring the distance between the zenith of the buccal gingival margin and the mucogingival line.[23]

Biological complications after loading were also assessed at the 5-year recall appointment. According to the latest updates,[10,11] peri-implant mucositis was defined as at least one soft-tissue peri-implant surface with positive BOP or pus on probing, PPD ≥4 mm, and no radiographically detectable bone loss. 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.[23]

We diagnosed peri-implantitis when an implant had simultaneously one surface with positive BOP or pus on probing, increasing PPD compared to previous examinations or PPD ≥5 mm in the absence of the previous examination data, and presence of radiographically detectable bone loss greater than 1 mm when compared with the loading measurements. As opposed to earlier 3-year studies on locking-taper implants,[8,22] the threshold for bone loss at a longer follow-up of 5 years was set at 1 mm. This was done 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.[10,11,13] In case of 6.0 mm 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.[23]

Study outcomes were implant survival, marginal bone loss and implant success after 5 years of follow-up, which were assessed according to covariates.[23]

In regard with implant survival, failure was considered as the need for implant removal either before loading (due to absence of osseointegration), or after loading (due to excessive bone loss). Implant survival was considered as the implant's state of being in function at the five-year follow-up evaluation, eg., symptom-free,

without mobility, radiolucency, or bone loss so severe as to warrant implant removal.[22,23,28,29]

Among survived implants, implant success was defined according to the following criteria[30,31] and to the defined bone loss threshold: absence of persistent pain, dysesthesia, or paraesthesia in the implant area; absence of peri-implant infection with or without suppuration; 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 loading to 5-year follow-up. Therefore, once the failed implants are excluded, implant success can be considered for survived implants without signs of peri-implantitis[23]; on the other side, survived implants with signs of peri-implantitis are not defined as successful.

By way of illustration, Figures 1 and 2 report some radiographic cases.

2.1 | Appendix of Materials and Methods

The locking-taper (Morse taper or Morse cone) dental implant system (Bicon Dental Implants, Bicon LLC) used in this study is characterized by a convergent crest module, platform switching, plateau root-form design, and an Integra CP surface (hydroxyapatite treated and acid-etched).[8,22,23]

A complete clinical and radiographic evaluation (dental and periodontal status; panoramic and periapical radiograph, cone beam computed tomography) and basic periodontal treatment was performed before implant placement. A pre-operative medication consisting of 2 g of Augmentin (875 mg amoxicillin plus 125 mg clavulanic acid), or 1 g of Klacid (Clarithromycin 500 mg) if allergic to penicillin, was given 1 h before surgery. All surgical procedures were performed under local anesthesia, using only Articain 4% with adrenaline 1:100 000 (Citocartin) or Articain 4% with adrenaline 1:100 000 (Citocartin) associated with oral sedation (Halcion 0.25 mg).[8,22,23]

A full-thickness flap was performed, and a high-speed 2.0 mm-diameter pilot drill (with a cutting edge at the apical portion and drilling at 1100 rpm) with external saline irrigation was used to perforate the cortical plate. Final pilot drilling length was determined by measuring residual bone height and adding at least 1.0 mm to the selected implant length to allow for a sub-crestal implant placement. Latch reamers presenting a 0.5 mm progressive increase in diameter were used at 50 rpm, without external irrigation to widen the osteotomy until the final implant diameter was reached. The selected implant was manually inserted into the osteotomy, a healing plug was placed in the implant well, and autogenous bone collected during the slow speed preparation of the osteotomy was used to fill the gap between the implant and the bony walls. The incisions were closed by single polyglycolic acid sutures (Vycril, ACE Surgical Supply Co.). A post-operative periapical radiograph was taken, post-operative instructions were given as well as antibiotic and analgesic prescriptions.[8,22,23]

After 4-to-6 months the implants were surgically uncovered, healing abutments were placed, and the mucosal flaps readapted around them. After three weeks of soft tissue healing, impressions were taken using a polyether material (3 M ESPE Impregum Impression Material). Definitive single-crown porcelain or composite restorations were placed within 2 weeks. The choice for restorative materials (porcelain or composite) was based on patients' preference, which was guided by personal economic resources in most of the cases. The technique used for the composite restorations was the Integrated

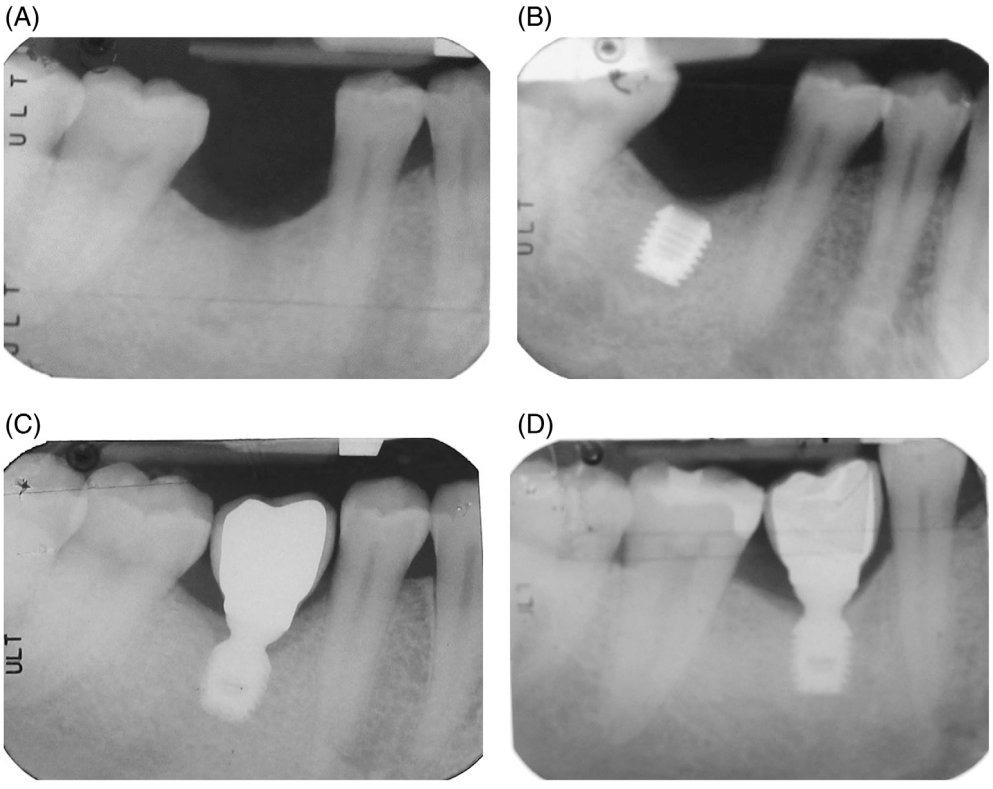

FIGURE 1 Single implant placed in 4.6 site (5 × 6 mm) in a patient without history of periodontal disease: (A) Pre-operative radiograph before implant placement; (B) Radiograph obtained at time of placement; (C) Radiograph obtained at time of loading; (D) Radiograph obtained at 5-year follow-up

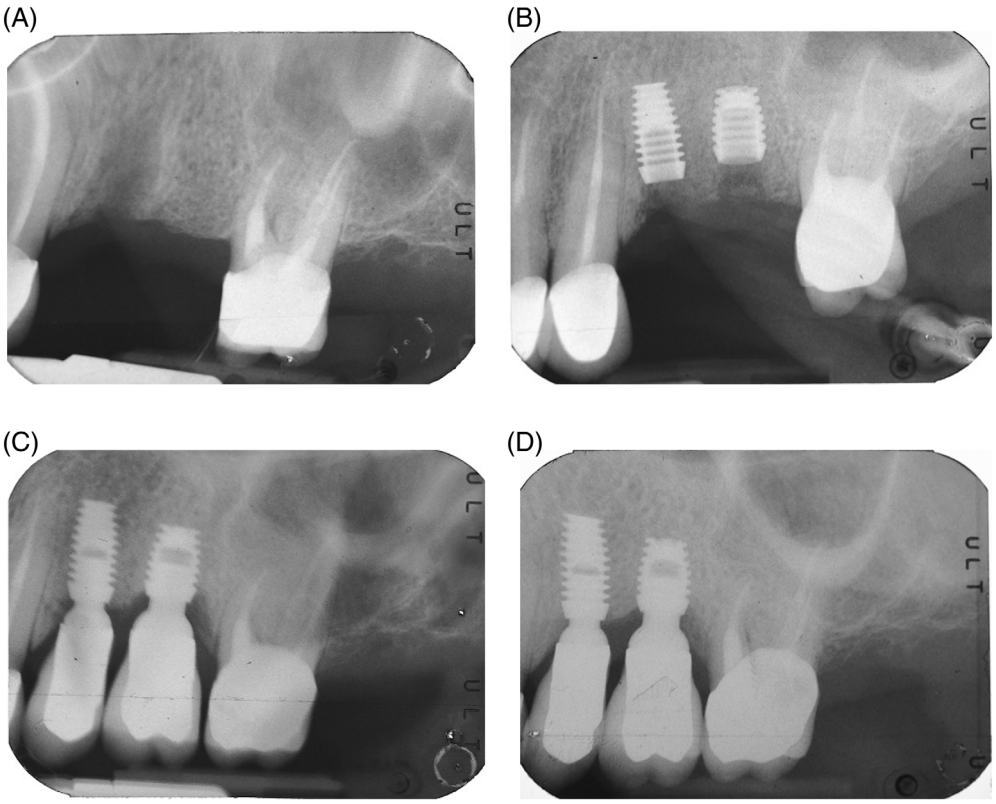

FIGURE 2 Single implants placed in 2.5 and 2.6 sites (4 × 8 mm and 4.5 × 6 mm) in a patient with history of periodontal disease: (A) Pre-operative radiograph before implant placement; (B) Radiograph obtained at time of placement; (C) Radiograph obtained at time of loading; (D) Radiograph obtained at 5-year follow-up

Abutment Crown (IAC), in which crowns are conventionally fabricated but also extra-orally cemented to the abutment, excess cement is removed and then the one-piece abutment and crown are inserted.[28] More precisely, the IAC is a cementless restoration for single-tooth implants, where the crown is extra-orally chemo-mechanically bonded to the coronal part of a titanium alloy non-shouldered or shouldered locking-taper abutment, reduced using carbide burs to provide for smooth surface contours and subgingival margins: in this way, the implant abutment and the crown material constitute one unit. The crown is inserted into place by mean a gentle tapping using a 250-g mallet, by mean a crown seating tip supplied by the manufacturer and a custom-made acrylic tapping jig to ensure accurate proper seating. When composite material was preferred for the crown, a micro-hybrid composite containing 73% by weight micro-fine ceramic particles, embedded in an organic polymer matrix (Ceramage, Shofu Inc), was used. In case of choice of ceramic material, a bilayer crown was planned using a zirconia framework veneered with feldspar ceramic (Ceramica Natural ZiR, Tressis Italia srl).[23]

Recall appointments were established to manage prosthetic complications as needed, and a maintenance program was designed to provide patients a professional oral hygiene session every 4 months.[23]

Peri-implant bone levels were measured through digitally scanned intraoral radiographs, performed with a paralleling technique, using Rinn centering devices (Rinn XCP Posterior Aiming Ring-Yellow, Dentsply). This was done immediately after implant placement, at healing abutment placement, at prosthetic loading, and after 5 years of loading. Measurements were taken as previously described.[8,22,23] The implant-abutment interface (IAI) was taken as a reference for measurements. CBL was measured on mesial and distal sides as the linear distance between the IAI and the highest point of the interproximal bone crest parallel to the lateral sides of the implant body: a positive value was given when the crest was located coronally to the IAI and a negative value when the crest was located apically to the IAI; for every implant, at each examination interval, an average mesial-distal value was calculated. 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; if F-BIC matches with IAI, the measurement was 0; if it is located apically, the measurement was a positive value.[8,22,23] As described in the literature, implants were divided into two groups on the basis of presenting a CIR less than or greater than two. The crown height was measured on the radiograph immediately after the prosthetic loading, from the most occlusal point to the IAI. Anatomical crown-to-implant ratio (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.[8,22,23]

Measurements were assessed with the aid of a software program (Rasband, W.S., ImageJ, U. S. National Institutes of Health, Bethesda, Maryland, USA) which uses a measuring tool in conjunction with a magnification tool. To correct the distortion of the radiographic image, the apparent size of each implant (measured directly on the radiograph) was compared with the actual length to determine, with adequate accuracy and precision, the amount of any changes of the crestal bone around each implant. Setting up the implant length as a known initial reference, the measurements were made to the nearest 0.01 mm. One dentist who was not involved in the treatment of the

TABLE 1 Overall implants and PP/NPP-groups distribution according to study variables

Variable	NPP	PP	Test statistic	d.f.	*p* value
Sex					
Male	52 (43.33)	98 (46.01)	$\chi^2 = 0.22$	1	NS ($p = 0.63$)
Female	68 (56.67)	115 (53.99)			
Age at follow-up	56.58 ± 10.99	61.26 ± 9.89	$F = 15.80$	1/333	<0.001
Smoking history					
No	88 (73.33)	180 (84.51)	$\chi^2 = 6.10$	1	0.01
Yes	32 (26.67)	33 (15.49)			
ASA status					
I	68 (56.67)	91 (42.72)	$\chi^2 = 5.98$	1	0.01
II	52 (43.33)	122 (57.28)			
Oral professional hygiene/year	3 (2)	3 (2)	$\chi^2 = 0.07$	1	NS ($p = 0.78$)
Use of interproximal oral hygiene devices					
No	28 (23.33)	47 (22.07)	$\chi^2 = 0.07$	1	NS ($p = 0.79$)
Yes	92 (76.67)	166 (77.93)			
Implant length					
5 mm	25 (20.83)	66 (30.99)	$\chi^2 = 4.07$	2	NS ($p = 0.13$)
6 mm	44 (36.67)	71 (33.33)			
8 mm	51 (42.50)	76 (35.68)			
Implant tooth site					
Premolar	47 (39.17)	99 (46.48)	$\chi^2 = 1.66$	1	NS ($p = 0.19$)
Molar	73 (60.83)	114 (53.52)			
Arch					
Posterior mandible	69 (57.50)	128 (60.09)	$\chi^2 = 0.21$	1	NS ($p = 0.64$)
Posterior maxilla	51 (42.50)	85 (39.91)			
Implant diameter					
3 mm	1 (0.83)	0 (0.00)			
3.5 mm	4 (3.33)	7 (3.29)	$\chi^2 = 6.94$	6	NS ($p = 0.32$)
4 mm	23 (19.17)	58 (27.23)			
4.5 mm	44 (36.67)	68 (31.92)			
5 mm	42 (35.00)	67 (31.46)			
6 mm	5 (4.17)	13 (6.10)			
6.5 mm	1 (0.83)	0 (0.00)			
Prosthetic material					
Resin	19 (15.97)	28 (13.15)	$\chi^2 = 0.49$	1	NS ($p = 0.48$)
Porcelain	100 (84.03)	185 (86.85)			
Crown-to-implant ratio					
<2	76 (63.87)	105 (49.30)	$\chi^2 = 6.54$	2	0.03
2–2.99	38 (31.93)	95 (44.60)			
>2.99	5 (4.20)	13 (6.10)			

Note: Age at follow-up and oral professional hygiene/year are presented as mean ± standard deviation and median (iqr); for all other variables, values are presented as *n* (%).
Abbreviations: NS, not statistically significant; d.f., degrees of freedom.

patients completed all the measurements on periapical radiographs; the observation intervals of radiographs were masked to the examiner. Before the start of the study, this investigator was calibrated for adequate intra- and inter-examiner levels of reproducibility in recording the radiographic parameters.[8,22,23]

The calibration for intra-examiner reproducibility was done with double recording of 25 measurements (25 implants), with an interval of 24 hours between the first and second recording. Three basic parameters, directly connected to CBL, F-BIC and CIR, were measured on three radiographs, utilized for this purpose: mesial CBL, mesial

F-BIC and crown height, all at prosthetic loading. An average value lower than 0.20 mm was considered reliable as threshold limit from a clinically point of view. According to Bland–Altman Method,[32] 3 plots were obtained, with respective average values of difference between each pair of measurements, together with confidence intervals (C.I.) of: 0.01 mm (95% C.I.[−0.06;0.09]) for mesial CBL at loading, 0.00 mm (95% C.I.[−0.04;0.04])for mesial F-BIC at loading, and − 0.01 mm (95% C.I.[−0.12;0.11]) for crown height.

Furthermore, the abovementioned exercise, according to the same method, was repeated by another dentist (always not involved in the treatments of patients) for inter-examiner reproducibility. The following respective average values of difference between each pair of measurements, together with C.I., were obtained: 0.00 mm (95% C.I.[−0.05;0.06]) for mesial CBL at loading, 0.00 mm (95% C.I. [−0.05;0.06]) for mesial F-BIC at loading, and 0.01 mm (95% C.I. [−0.04;0.06]) for crown height.

For data collection, a database including all patients evaluated in the study was created with Microsoft Excel. All data analysis was carried out using Stata v.13.0 for Macintosh (StataCorp). The normality assumptions for continuous data were assessed by using the Shapiro–Wilk test; mean and standard deviation were reported for normally distributed data, median and interquartile range (iqr) otherwise. 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 comparison between the means of continuous variables in two different times was performed by using paired Student's "*t*" test or Wilcoxon matched-pairs signed-rank test. The comparison between the means of two different groups was performed using unpaired Student's "*t*", or Wilcoxon rank-sum test. The comparison of the means among more than two groups was done using one-way analysis of variance (ANOVA), or Kruskal-Wallis equality-of-populations rank test. A multivariate analysis (logistic regression) was carried out to find factors associated with implant success. Significance level was set at 0.05.[8,22,23]

The study presents compliance with the STROBE checklist guidelines.[33]

3 | RESULTS

Of the 333 implants placed in 142 patients (65 men and 77 women), 213 (63.96%) and 120 (36.04%) were respectively positioned in PP and NPP.[23] Furthermore, CIR in PP and NPP was respectively 2.01 ± 0.87 (range 0.91–3.81) and 1.78 ± 0.79 (range 1.05–3.52), with statistically significant differences among groups ($p = 0.002$). The implants distribution, analyzed according to PP and NPP, is presented in Table 1.

As one early failure in one patient was assessed, the overall implant-based survival at 60-month follow-up was 96.1%: 96.67% (116/120) in NPP and 95.77% (204/213) in PP, without significant differences between groups ($p = 0.77$).[23] Peri-implantitis revealed to be the cause of failure in six out of nine cases (66.7%) of failed implants in PP, but in none of failed implants in NPP. The distribution of different variables related to failed implants is reported in Table 2.

ΔCBL was 0.61 (0.87) mm and 0.74 (1.54) mm respectively in NPP and PP, with statistically significant differences between groups ($p = 0.04$). ΔF-BIC was 0.01 (0.43) mm and 0.09 (0.79) mm respectively in NPP and PP, with no statistically significant differences between groups ($p = 0.08$).[23]

Table 3 reports soft tissues conditions (PPD, mBI, mPLI and KT) at 5-year recall appointment, according to length-groups, arch-groups or PP/NPP-groups. Peri-implantitis was found in 3 (2.59%) and 16 (7.84%) cases in NPP and PP respectively, with no statistically significant differences between groups ($p = 0.08$).[23] The overall implant-based success at 60-month follow-up was 94.06% (301/320)[23]:

- 92.16% for PP (respectively 36.7% in 8-mm length, 32.45% in 6-mm length and 30.85% in 5-mm length);
- 97.41% for NPP (respectively 43.36% in 8-mm length, 36.28% in 6-mm length and 20.36% in 5-mm length).

Regarding prevalence of mucositis, no significant differences ($p < 0.05$) were found between groups regarding PP/NPP, length or arch-groups (Table 4).

TABLE 2 Failures features and cause of failures

Site	16	24	24	26	34	35	35	44	45	46	46	47	17
Diameter	5	4	4	5	4.5	4	4.5	5	6	4	4.5	5	5
Length	6	5	8	6	8	5	6	8	5	5	8	6	6
Sex	m	f	f	f	m	f	m	m	m	f	m	f	m
Smoking history	yes	no	no	yes	yes	no	no	no	no	no	no	no	no
ASA status	II	I	I	II	II	II	I	II	I	II	I	II	I
Oral professional hygiene/year	3	4	2	1	2	4	2	4	3	2	4	4	4
History of periodontal disease	yes	no	yes	yes	yes	yes	yes	yes	yes	yes	no	no	no
Crown-to-implant ratio	2.68	2.25	1.57	1.89	1.69	2.85	1.96	1.62	2.76	3.15	1.38	2.17	/
Failure	late	late	late	late	late	late	late	late	late	late	late	late	early
Cause of failure	ep	ep	fp	peri	peri	peri	ep	peri	peri	peri	ep	rp	ep

Abbreviations: ep, error of placement; peri, peri-implantitis; rp, retrograde peri-implantitis; fp, fracture of the post of the abutment.

TABLE 3 Overall soft tissues indices (mBI, mPLI, PPD [mm], KT [mm]) according to PP/NPP-groups, length-groups and arch-groups

Variable	mBI [median (iqr)]	test statistic	d.f.	p value
Overall	0.87 (0.84)			
History of periodontal disease				
No	0.84 (0.87)	$Z = -1.36$		NS ($p = 0.17$)
Yes	0.98 (0.89)			
Arch				
Posterior mandible	0.91 (0.9)	$Z = -0.5$		NS ($p = 0.61$)
Posterior maxilla	0.95 (0.86)			
Implant length				
8 mm	0.81 (0.8)			
6 mm	0.9 (0.894)	$\chi^2 = 7.47$	2	$p = 0.02$
5 mm	1.13 (0.89)			
Variable	**mPLI [median (iqr)]**	**test statistic**	**d.f.**	**p value**
Overall	0.54 (0.70)			
History of periodontal disease				
No	0.52 (0.65)	$Z = 0.16$		NS ($p = 0.86$)
Yes	0.55 (0.73)			
Arch				
Posterior mandible	0.62 (0.74)	$Z = 2.66$		$p = 0.007$
Posterior maxilla	0.41 (0.63)			
Implant length				
8 mm	0.38 (0.57)			
6 mm	0.65 (0.81)	$\chi^2 = 8.48$	2	$p = 0.01$
5 mm	0.6 (0.68)			
Variable	**PPD [median (iqr)]**	**test statistic**	**d.f.**	**p value**
Overall	3.41 (1.27)			
History of periodontal disease				
No	3.04 (0.95)	$Z = -1.76$		NS ($p = 0.07$)
Yes	3.2 (0.94)			
Arch				
Posterior mandible	3.01 (0.89)	$Z = -3.01$		$p = 0.002$
Posterior maxilla	3.34 (0.99)			
Implant length				
8 mm	3.08 (0.78)			
6 mm	3.05 (0.92)	$\chi^2 = 6.86$	2	$p = 0.03$
5 mm	3.35 (1.15)			
Variable	**KT [median (iqr)]**	**test statistic**	**d.f.**	**p value**
Overall	1.84 (1.42)			
History of periodontal disease				
No	1.93 (1.49)	$Z = 0.75$		NS ($p = 0.44$)
Yes	1.76 (1.39)			
Arch				
Posterior mandible	1.86 (1.43)	$Z = 0.6$		NS ($p = 0.54$)
Posterior maxilla	1.77 (1.43)			

TABLE 3 (Continued)

Variable	KT [median (iqr)]	test statistic	d.f.	p value
Implant length				
8 mm	1.59 (1.26)			
6 mm	2 (1.52)	$\chi^2 = 4.8$	2	NS ($p = 0.09$)
5 mm	1.94 (1.49)			

Note: mBI, mPLI, PPD and KT are presented as median (iqr).
Abbreviations: NS, not statistically significant; d.f., degrees of freedom.

TABLE 4 Prevalence of peri-mucositis according to PP/NPP-groups, length-groups and arch-groups

Variable	No Peri-Mucositis *n* (%)	C.I.	Peri-Mucositis *n* (%)	C.I.	χ^2	d.f.	p value
History of periodontal disease							
No	107 (92.24)	[85.69;95.93]	9 (7.76)	[4.06;14.3]	0.08	1	NS ($p = 0.76$)
Yes	190 (93.14)	[88.71;95.9]	14 (6.86)	[4.09;11.28]			
Arch							
Posterior mandible	173 (91.53)	[86.59;94.76]	16 (8.47)	[5.23;13.4]	1.13	1	NS ($p = 0.28$)
Posterior maxilla	124 (94.66)	[89.15;97.44]	7 (5.34)	[2.55;10.84]			
Implant length							
8 mm	76 (87.36)	[90.54;98.3]	11 (12.64)	[1.69;9.45]	5.79	2	NS ($p = 0.06$)
6 mm	103 (93.64)	[87.17;96.95]	7 (6.36)	[3.04;12.82]			
5 mm	118 (95.93)	[78.49;92.89]	5 (4.07)	[7.1;21.5]			

Note: For all variables, values are presented as *n* (%).
Abbreviations: NS, not statistically significant; d.f., degrees of freedom; C.I., confidence interval.

4 | DISCUSSION

Over the last decades, implant placement has become a widespread and predictable methodology of treatment for partially edentulous posterior regions. As sufficient bone volume available for standard-length implant rehabilitation is not always present, the use of short implants (<6-mm) is frequently chosen among clinicians as a minimally invasive treatment modality, for the reduction of number of major surgeries, potential morbidity, times and costs.[34–37] Recent metanalysis reported that short implants have almost comparable outcomes, in terms of implant survival, marginal bone loss and peri-implant complications, to standard-sized dental implant (>6-mm) and may be considered a valid alternative therapy to augmentation procedures for maxillary and mandibular jaw atrophies.[2,3,6,38,39]

Nevertheless, while a large amount of research data on long-term success of standard and short implants in periodontally healthy patients is currently available, only few short-term studies (3-year follow-up) are present in the literature about the influence of periodontitis on the implant survival of short implants in PP, and they do not allow for definitive conclusions.[20,21,40–42] Han et al.,[40] in a retrospective study in which two or three splinted implants 6 mm-length and 4 mm-diameter were placed in each patient, found a one-year survival rate of 95.8% for 95 short implants; the great majority of participants had chronic periodontitis (77.1%). Correia et al.,[41] in a 3-year retrospective study on 202 patients and 689 implants of different types, design and implant-abutment connections, of which 45.2% (301 implants) rehabilitated with single crowns, declared an overall implant survival of 97.3% for 116 short implants placed in NPP and of 93.1% for 156 placed in PP; the latter seemed to present a greater, even if not statistically significant, risk of implant failure after 3 years, when compared with implants placed in NPP. The present study, which, to the best of our knowledge, is the first study concerning short and ultra-short implants supporting single crowns in PP, 333 implants, characterized by a plateau-design and a locking-taper implant-abutment connection, showed an implant survival of 96.1% after 5 years of loading. These results are consistent with the study of Hasanoglu et al.,[21] a retrospective evaluation with an average follow-up of 33.5 months, which reported an overall implant survival of 95.86%, for 460 short implants (4-to-9 mm in length) of different brands.

After splitting the sample of placed implants in NPP and PP-groups (36.04% and 63.96% respectively), significantly different implant survival were not found (96.67% and 95.77% for NPP and PP, $p = 0.77$). Although some authors in the literature recommend not to use short implants to support single crowns, due to the possible risk of overloading for high CIR,[7,43,44] in the present study, not only short implants, but also ultra-short implants, offered a favorable implant survival after 5 years; moreover, outcomes were not different among

implant length-groups and PP/NPP-groups. These results are consistent with those found in a previous 3-year retrospective study of the same authors,[22] where, with the same type of implant utilized, a survival rate of 98.08% for 208 implants placed in 77 PP and of 96.61% for 118 implants placed in 63 NPP was assessed.

The favorable bone levels stability showed in this study by both short and ultra-short implants may be explained by the specific macro-design of these implants, characterized by the presence of a screw-less, 3° locking-taper implant-abutment connection. This connection confers an impervious seal to microbial penetration or infiltration,[45] and a greater mechanical stability to the implant-crown assembly, with absence of micro movements and micro gaps at the implant-abutment interface, which lead to minimal bone resorption.[6,7] The plateau-design allows from an initial woven bone formation at the healing chambers and further bone morphologic evolution toward a haversian-like configuration that over time increases significantly in mechanical properties.[22,23,45–47] In this way, adjacent bone is hardly loaded at levels that could exceed the minimum effective strain necessary for bone modeling and remodeling.[48,49] Nevertheless, after 5 years of loading, greater values of marginal bone loss and apical shift of F-BIC were found in PP. Even if these differences can be considered as minimally relevant, ΔCBL was 0.61 and 0.74 mm respectively in NPP and PP, with statistically significant differences between groups ($p = 0.04$).

Despite the promising outcomes in term of survival rate and bone levels, in accordance with the general consensus existing in literature,[50] indicating that PP are at higher risk for peri-implantitis and marginal bone loss compared to NPP, the present study showed an overall negative influence of history of periodontitis on implant survival and success. Peri-implantitis revealed to be the cause of failure in six out of nine cases (66.7%) of failed implants in PP, but in none of failed implants in NPP, which were lost for other causes (error of placement, retrograde peri-implantitis,[13] mechanical fracture of the abutment's component). Authors consider this outcome as clinically relevant, underlying that history of periodontitis seems to be connected to peri-implantitis in terms of cause of failure. This finding is also consistent with the report of Hasanoglu,[21] who found peri-implantitis as the greater cause of failure in implants placed in PP, but not in NPP. In regard with retrograde peri-implantitis, it is reported as a periapical radiographic lesion different from peri-implant infection at sites with deepened PPD, and directly correlated, in most of cases, with existing periapical endodontic lesions at adjacent teeth.[13]

With the threshold limit for defining peri-implantitis set at 1 mm of bone resorption 5 years after loading, among 320 survived implants, 19 (5.94%) presented peri-implantitis, 3 (2.59%) and 16 (7.84%) in NPP and PP respectively: this difference between the two groups, even if not statistically significant ($p = 0.08$), shows to be relevant from a clinical point of view. At this proposal, as the chosen 1-mm limit for bone loss may appear very stringent, authors underline that 2-mm limit, currently used in the literature as a 5-year follow-up threshold[51] cannot be considered acceptable for the definition of a potentially dangerous condition as peri-implantitis around implants that are only 5 or 6 mm long.[10,11]

Our findings agree with other studies on standard implants with the same follow-up in PP.[51–55] Martens et al.,[52] in a case series with 57-months of follow-up on 163 implants in 33 periodontally compromised patients, found a survival rate of 96.3% and a percentage of peri-implantitis of 6%. Aguirre-Zorzano et al.,[53] in a cross-sectional study with 786 implants in 239 patients all with history of periodontitis, found a percentage of peri-implantitis of 9.8%. Canullo et al.,[54] in a cross-sectional study with 1507 implants in 534 patients including also subjects with history of periodontitis, found a percentage of peri-implantitis of 7.3%, with a higher percentage of healthy periodontal subjects in the group not affected by peri-implantitis. Konstantinidis et al.,[55] in a cross-sectional study with a mean follow-up of 5.5 years on 597 implants in 186 patients, including also subjects with history of periodontitis, found a percentage of peri-implantitis of 6.2%. Dalago et al.,[51] in a cross-sectional study with 916 implants in 183 patients, found a percentage of peri-implantitis of 7.3%; this study considered factors related to patient's conditions, implant's characteristics and clinical parameters, finally assessing history of periodontitis and total rehabilitations as risk indicators for peri-implantitis.

Finally, insurgence of mucositis is strictly related to inadequate plaque control,[56,57] typical of a reversible inflammation which can lead to a non-reversible disease: in the present study all patients showed a positive compliance to the maintenance program, following a specific protocol of professional oral hygiene recalls, and, according to the literature,[58,59] low inflammatory indexes were registered both in PP and NPP after 60 months of follow-up, as reported by other studies on short and ultra-short locking-taper implants.[26,29] The design and type of the implant supported prosthesis can influence the cleanability of the implant site[8,22,23,60]: single-crown rehabilitation used in the study represent a gold standard in facilitating plaque removal.[26,28,61]On the other hand, as reported in another study on the same sample of patients,[23] percentages of success, even if not statically different between groups, were respectively lower in 5.0 and 6.00 mm-length implants (93.10% and 92.73%) compared to 8.0 mm-length implants (95.93%).

To the best of our knowledge, the evidence regarding the possible association between the width of keratinized mucosa and the success of ultra-short implants is scarce in literature and still inconclusive. However, it is well known that a good level of oral hygiene is also related to an adequate width of keratinized tissue.[62] At the same time, the presence of an appropriate width and thickness of KT may facilitate soft tissues flap management during surgical procedures and also represent a favorable feature for clinical improvement after peri-implantitis treatments.[63] It does not therefore seem inappropriate to suggest that ultra-short implants require continuous monitoring of patient's compliance and extra attention during supportive therapy, particularly in case of implants placed in mandibular sites, which do not easily allow surgical procedures for soft tissues augmentation.[64] Comparing the outcomes of this study with the previous similar studies on locking-taper implants done at 3-year follow-up, some issues remain critical. Main limitations[23] related to its retrospective nature, even if reduced, still consist in a non-balanced distribution among implant length-groups, PP/NPP-groups and arch-groups, besides the University setting (single-centre). However, a proper evaluation of clinical and radiographic conditions at a longer-term follow-up (5 years), as well as limiting the present analysis to single crown restorations, suggests predictability of treatments using short and ultra-short locking-taper implants even in presence of history of periodontitis.

5 | CONCLUSIONS

Outcomes of the present study revealed that history of periodontitis represents a crucial factor for the success of short and ultra-short implants, which need to be strictly monitored.

These 5-year results showed that short and ultra-short locking-taper implants supporting single-crown restorations may represent a successful treatment for the rehabilitation of the atrophic posterior jaws both in PP and NPP, provided that patients are enrolled in a specific supportive protocol, carrying out adequate home care procedures and compliance with recall appointments. Regular attendance to a maintenance program may play an important role in determining stable results over time and in preventing peri-implant diseases, avoiding the worsening of mucositis in potential peri-implantitis. Further investigations with longer follow-up and prospective design are of course necessary to validate these conclusions.

AUTHOR CONTRIBUTIONS

Giorgio Lombardo: Concept and design, critical revision and approval of article. Annarita Signoriello: Data collection and analysis, planning of statistics, drafting article. Alessia Pardo, Xiomara Zilena Serpa Romero, Luisa Arévalo Tovar: Data collection and analysis. Luis Armando Vila Sierra, Pier Francesco Nocini: Critical revision and approval of article. Mauro Marincola: Concept and design, critical revision and approval of article

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CONFLICT OF INTEREST

All authors declare no conflicts of interests.

DATA AVAILABILITY STATEMENT

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

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