Survival of Short and Ultra-Short Locking-Taper Implants Supporting Single Crowns in the Posterior Mandible: A 3-Year Retrospective Study

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The purpose of this retrospective study was to determine survival and peri-implant marginal bone loss of short and ultra-short implants placed in the posterior mandible. A total of 98 patients received 201 locking-taper implants between January 2014 and January 2015. Implants were placed with a 2-stage approach and restored with single crowns. Clinical and radiographic examinations were performed at 3-year recall appointments. At that time, the proportion of implant survival by length, and variations of crestal bone levels (mean crestal bone loss and mean apical shift of the "first bone-to-implant contact point" position) were assessed. Significance level was set at 0.05. The total number of implants examined 36 months after loading included: 71 implants, 8.0 mm in length; 82 implants, 6.0 mm in length; and 48 implants, 5.0 mm in length. Five implants failed. The overall proportion of survival was 97.51%, with 98.59% for the 8.0-mm implants, 97.56% for the 6.0-mm implants, and 95.83% for the 5.0-mm implants. No statistically significant differences were found among the groups regarding implant survival ($P = .73$), mean crestal bone loss ($P = .31$), or mean apical shift of the "first bone-to-implant contact point" position ($P = .36$). Single-crown short and ultra-short implants may offer predictable outcomes in the atrophic posterior mandibular regions, though further investigations with longer follow-up evaluations are necessary to validate our results.

Key Words: bone loss, mandible, short implant, single crown, survival, ultra-short implant

INTRODUCTION

The use of dental implants has been widely accepted in the treatment of partially and totally edentulous patients. Post-extraction bone remodeling usually leads to height and thickness reductions, which in turn represent important limits to implantology procedures.[1–3] Important anatomical structures, such as the inferior alveolar nerve and maxillary sinus, are thus frequently exposed to increased risk of damage.[4,5]

The rehabilitation of posterior maxillary and mandibular extreme atrophies require sufficient residual bone levels; therefore, they often necessitate major surgical procedures, such as zygomatic implants, onlay block grafts, elevation of the maxillary sinus, lateralization of the inferior alveolar nerve, and osteodistraction.[6–13] These solutions, however, increase patient morbidity and the chance of intra- and post-operative complications.[5,6]

As an alternative and minimally invasive treatment option, the use of short implants was suggested.[4,14] The classification of short implants in scientific literature has evolved over time. The recent European Consensus Conference[15] on short, angulated, and diameter-reduced implants has defined standard implants as those $>$8.0 mm in length and $\geq$3.75 mm in diameter, short implants as those with $\leq$8.0 mm in length and $\geq$3.75 mm in diameter, and ultra-short implants as those $\leq$5.0 mm in length.

Short implants, compared to conventional implants, were historically associated with lower proportion of survival and success, and usually related to unpredictable long-term outcomes.[16–19] Nevertheless, recent scientific evidence pointed out their design and surface improvements, suggesting similar implant survival and success for short and for standard implants ($>$8 mm).[14]

The majority of the authors focus primarily on the clinical outcomes of standard and short implants,[20–23] whereas documentary proof for ultra-short implants in the posterior jaw is less consistent, leaving incomplete recommendations at this time for their clinical usage.[24]

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Furthermore, restorative variables are rarely considered in the analysis of implant survival and success of short and ultrashort implants.[5,25] More specifically, available studies often report the outcomes of prosthetic rehabilitations based upon differing prosthetic variables types, such as single crowns, fixed partial dentures and overdentures.[26] In so doing, the comparative interpretation of the results becomes difficult, like comparing apples to oranges.

That said, several studies[24,25,27–29] on short and ultrashort implants report that fixed partial prostheses are preferred in cases of reduced implant length and in cases of large reverse crown-to-implant ratios. The opinions expressed are due to concerns over the potential for screw loosening, screw fracture, or implant fracture. However, in terms of better oral hygiene access and framework passivity,[25] individual restorations continue to represent a gold standard.

Peri-implant marginal bone loss is considered a crucial factor for long-term implant success and stability of osseointegration.[30] Despite the discrepancies between authors about the definition of success criteria,[31–34] a marginal bone loss not more than 2.0 mm after w years of loading is generally accepted as consistent with implant health.[35–37]

We hypothesized that short and ultra-short locking-taper implants, restored with single crowns in the atrophic posterior mandible, can constitute a successful therapy considering a short-term follow-up.

Thus, this 3-year retrospective study aimed to analyze implant survival and peri-implant marginal bone loss between 5.0 mm, 6.0 mm, and 8.0 mm-length locking-taper implants placed in the edentulous posterior mandible and restored with single crowns.

Materials and Methods

Study design and inclusion criteria

All patients referred to the University Dental Clinic between January 2014 and January 2015 were treated with implant-supported single-crowns for edentulism (tooth loss caused by trauma, caries, or periodontal disease) in the posterior mandible. A retrospective study was conducted between May and July 2018 with a 36-month follow-up.

Patients recruited for the study met the following inclusion criteria: aged between 18 and 90 years old; treated with less than 10 mm of alveolar bone height available above the inferior alveolar nerve in the partially edentulous mandible; received at least one 8.0-mm, 6.0-mm, or 5.00-mm locking-taper dental implant supporting a single crown; and had no preoperative consent for bone augmentation procedures.

Patients recruited for the study met the following exclusion criteria: insufficient oral hygiene; heavy smoking (>20 cigarettes/day); uncontrolled diabetes mellitus; pregnancy; radiotherapy to head or neck within 2 years prior to treatment; recent history of chemotherapy; American Society of Anesthesiologists (ASA) classification status IV or V; severe autoimmune diseases; metabolic bone disorders, or a history of intravenous bisphosphonate therapy.

The study was approved by the University Institutional Review Board (Prot. 30479, IMPCONOMAND, 17/05/18). The nature and aim of the study, together with the anonymity in the scientific use of data, were clearly explained in a written, informative consent form, which was signed by every patient. All procedures accorded with Helsinki Declaration and good clinical practice guidelines for research on human beings.

Surgical protocol

The locking-taper (Morse taper or Morse cone) dental implant system (Bicon Dental Implants, Boston, Mass; designed in 1985) used in this study (Figure 1) presents an implant interface connection to its restoration, which is impervious to bacterial penetration or infiltration.[38] The implant system also includes a convergent crest module, platform switching, plateau root-form design, and an Integra CP surface (hydroxyapatite treated and acid-etched).

All treatments and visits were carried out by a single clinician. A complete clinical and radiographic evaluation (dental and periodontal status; panoramic and periapical radiograph, computerized tomography scan) and periodontal basic treatment were performed before implant placement; if needed, surgical templates were fabricated; amoxicillin plus clavulanate (Augmentin, GlaxoSmithKline, Verona, Italy) was prescribed 1 hour before surgery to prevent infections.

For anesthesia, which was local and infiltrative, 2% xylocaine (Dentsply Pharmaceutical, York, Pa) was used. 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 subcrestal 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 the autogenous bone collected from the slow speed drilling process was used to fill the gap between the implant and the bony walls. The incisions were closed by single polyglycolic acid sutures (Vicril, ACE Surgical Supply Co, Brockton, Mass).

A post-operative periapical radiograph was taken, and the patient received instructions along with antibiotic and analgesic prescriptions.

Prosthetic protocol and follow-up evaluation

After 4 to 6 months, the implants were uncovered, and healing abutments were placed. After 3 weeks of soft tissue healing, definitive impressions were taken using a polyether material (3M ESPE Impregum Impression Material). Definitive single-crown porcelain or composite restorations were delivered within 2 weeks. The choice for restorative materials (porcelain or composite) was based on patients' preference, guided by personal economic resources in most of the cases. The technique used for the restorations was the integrated abutment crown, in which the abutment and the crown material are extra-orally chemo-mechanically bonded; therefore, there is no need for

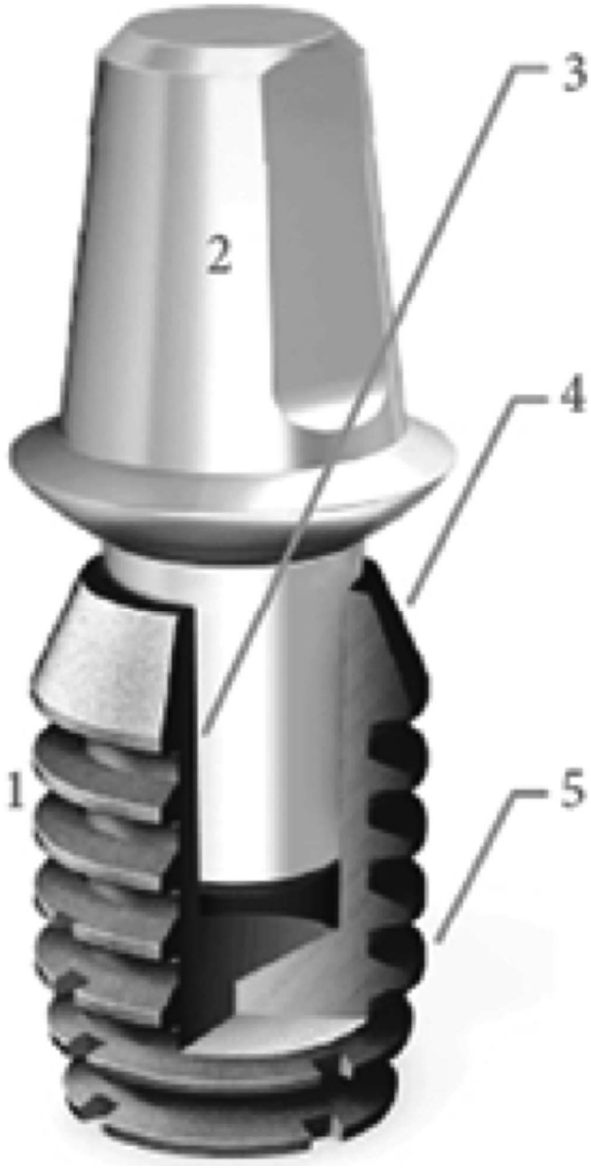


Figure 1. Schematic drawing of Bicon dental implant system and its macro-geometric features. (1) Root-plateau form implant body; (2) abutment; (3) 1.5° internal connection (locking-taper); (4) convergent crest module (sloping shoulder); (5) implant plateau.

cement, and the implant and implant-abutment are connected with a screwless locking-taper connection.[39]

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

Clinical assessment of peri-implant soft tissues and radiographic examinations were performed after 3 years of follow-up from loading time.

By way of illustration, Figures 2–7 report some radiographic cases.

Study variables and outcomes

Implant lengths considered in this study were 8.0 mm, 6.0 mm, and 5.0 mm; implant diameters were 4.0 mm, 4.5 mm, 5.0 mm, and 6.0 mm.

Covariates included: sex, age, smoking history, history of periodontal disease, ASA status, number of oral hygiene sessions per year, tooth site, prosthetic material, and crown-to-implant ratio (CIR).

The main outcome was implant survival[1,20,40] after 3 years of follow-up. Implant failure was considered as the need for implant removal either before loading (due to no osseointegration) or after loading (due to excessive bone loss). Implant survival was considered as the implant's state of being in function at the 3-year follow-up evaluation.

Secondary outcomes included crestal bone level variations, that is, a descriptive analysis of crestal bone level (CBL, average bone level around implants at mesial and distal sides, in mm) and first bone-to-implant contact (F-BIC, in mm),[41–43] along with their variations ΔCBL (average bone loss) and ΔF-BIC (average apical shift of the "first bone-to-implant contact point" position). These values were determined based on changes that took place between loading time (t_0, considered as baseline time) and the 3-year follow-up time (t_1), according to covariates.

Peri-implant bone levels were measured through digitally scanned intraoral radiographs, performed with parallel technique[44] using Rinn centering devices (Rinn XCP Posterior Aiming Ring-Yellow, Dentsply, Elgin, Ill), immediately after implant placement, at healing abutment placement, at prosthetic loading, and after 3 years of loading. 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 was given when the crest was located apically to the IAI. For every implant, an average mesial-distal value was calculated at each examination interval.

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 matched with IAI, the measurement was 0; if it was located apically, the measurement was a positive value.

As described in the literature,[45] implants were divided into 2 groups on the basis of presenting a CIR less than or greater than 2. 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[45] (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.

Measurements (Figure 8) were assessed with the aid of a software program (Rasband, W.S., ImageJ, US National Institutes of Health, Bethesda, Md) 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

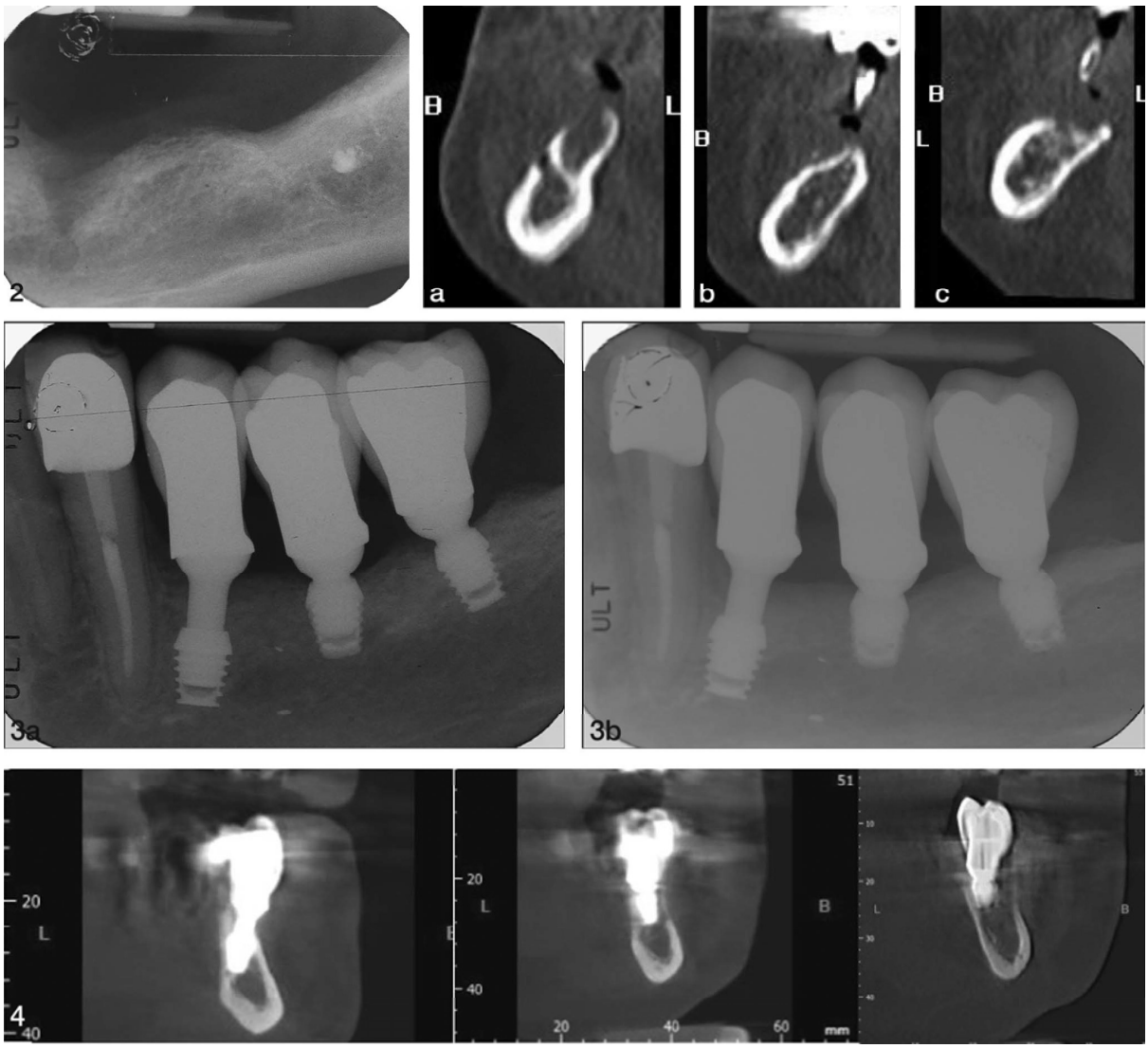


Figure 2–4. Figure 2. 3 implants (4.0 × 5.0 mm, 4.0 × 5.0 mm, and 4.0 × 5.0 mm) placed in #21, #19, and #18 sites. (a) Pre-operative radiograph before implant placement. (b) Cone beam computerized tomography obtained before implant placement. **Figure 3.** 3 implants (4.0 × 5.0 mm, 4.0 × 5.0 mm, and 4.0 × 5.0 mm) placed in #21, #19, and #18 sites. (c) X ray obtained at loading time; (d) X ray obtained at 3-year follow-up. **Figure 4.** Three implants (4.0 × 5.0 mm, 4.0 × 5.0 mm, and 4.0 × 5.0 mm) placed in #21, #19, and #18 sites. Cone beam computerized tomography obtained at 3-year follow-up.

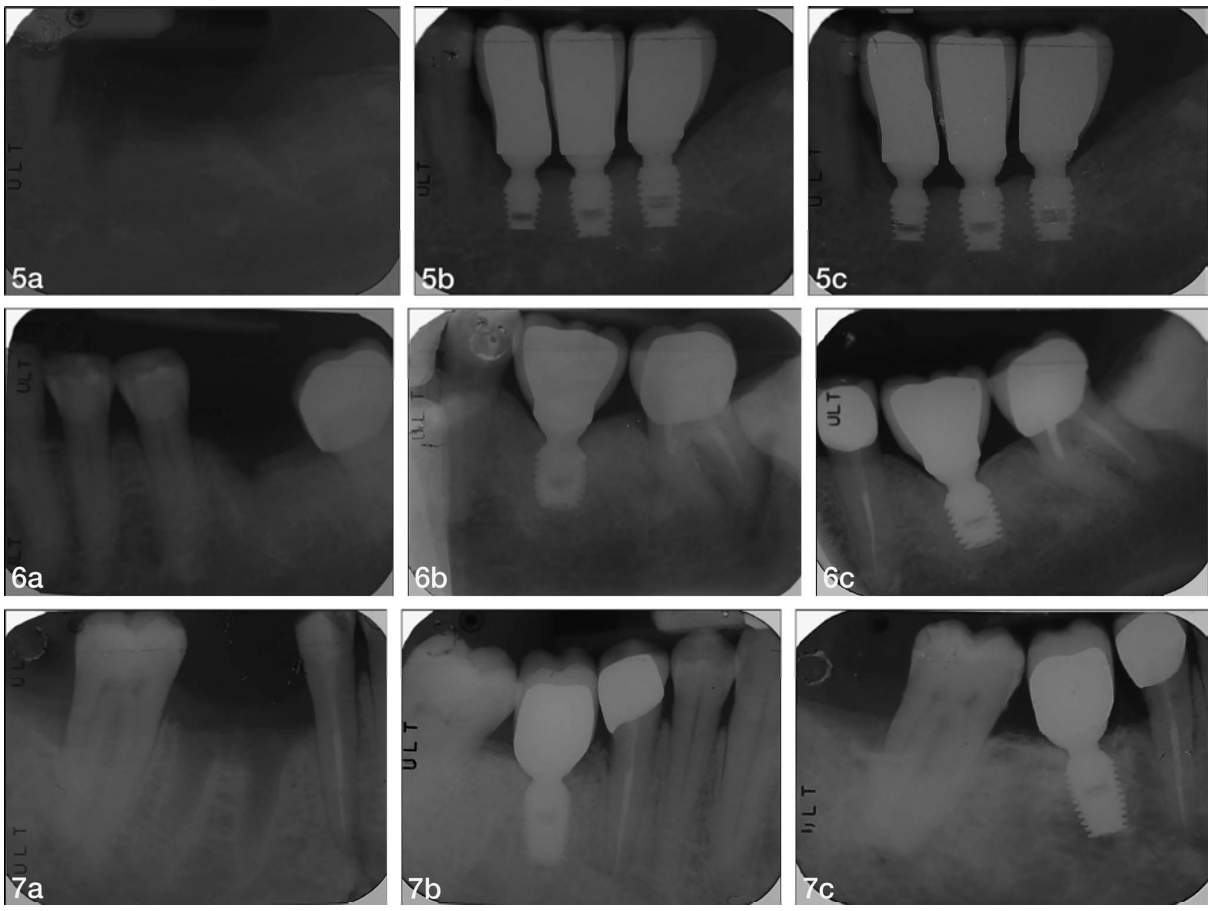
actual length of the implant, to determine with adequate precision the amount of change in the crestal bone around each implant. The measurements were made to the nearest 0.01 mm.

One dentist, who was not involved in the treatment of the patients, completed all the measurements on periapical radiographs; the observation intervals of the radiographs were masked to the examiner. Before the start of the study, this investigator was calibrated for intra-examiner adequate levels of accuracy and reproducibility in recording the radiographic parameters. Three radiographs were used for this purpose: duplicate measurements for CBL, F-BIC, and CIR were collected with an interval of 24 hours between the first and second recording. The intra-class correlation coefficients, used as a measure of intra-examiner reproducibility, had to be greater than 0.8.

Statistical analysis

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, College Station, Tx).[46]

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,



Figures 5–7. Figure 5. Three implants (4.0 × 5.0 mm, 4.5 × 6.0 mm, and 4.5 × 6.0 mm) placed in #20, #19, and #18 sites. (a) Pre-operative radiograph before implant placement. (b) X ray obtained at loading time. (c) X ray obtained at 3-year follow-up. **Figure 6.** One implant (5.0 × 6.0 mm) placed in #19 site. (a) Pre-operative radiograph before implant placement. (b) X ray obtained at loading time. (c) X ray obtained at 3-year follow-up. **Figure 7.** One implant (5.0 × 8.0 mm) placed in #30 site. (a) Pre-operative radiograph before implant placement. (b) X ray obtained at loading time. (c) X ray obtained at 3-year follow-up.

absolute frequencies, percentages, and 95% confidence intervals were reported. The association between categorical variables was tested with $\chi 2$ 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 *t* test or Wilcoxon matched-pairs signed-rank test. The comparison between the means of 2 different groups was performed using unpaired Student *t* or Wilcoxon rank-sum test. The comparison of the means among more than 2 groups was done using one-way analysis of variance (ANOVA) or Kruskal-Wallis equality-of-populations rank test. Significance level was set at 0.05. The methodology was reviewed by an independent statistician.

Results

A total of 98 patients (43 men and 55 women) were identified for the retrospective study according to inclusion and exclusion criteria.

Mean age at placement was 54.07 ± 10.67 years old (range: 32–77). In all, 79.6% of the patients were non-smokers, 50% presented an ASA status I, and 65.28% reported a history of periodontal disease. Patients were compliant with the maintenance program, following a mean of 3.85 ± 1.17 oral professional hygiene sessions in a year.

A total of 71 implants (35.32%) were 8.0 mm in length, 82 (40.8%) were 6.0 mm in length, and 48 (23.88%) were 5.0 mm in length. Implant diameters were 4.0 mm (33.83%), 4.5 mm (32.83%), 5.0 mm (26.37%), and 6.0 mm (6.97%). Most of the implants were placed in the molar area, predominantly in #19 and #30 sites (22.39% and 21.89%, respectively).

All the implants were restored with single crowns: 180 porcelain crowns and 21 resin crowns. Mean CIR was 1.96 ± 0.63 (range: 0.92–3.81): 1.42 ± 0.32 (range: 0.92–3.07), 1.99 ± 0.4 (range: 1.09–2.8) and 2.71 ± 0.47 (range: 1.81–3.81) for implants that are 8.0 mm, 6.0 mm, and 5.0 mm in length, respectively. A CIR > 2 prevalence was estimated in 42.78% of the implants, with significant differences ($P < .001$) among

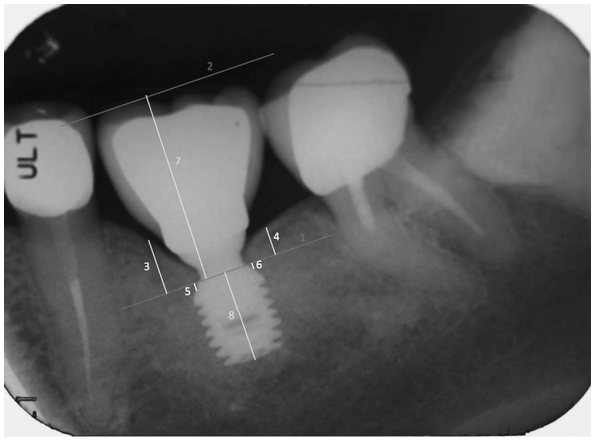


Figure 8. Schematic example of the references for peri-implant bone levels measurements. (1) Implant-abutment interface; (2) most occlusal point line; (3) crestal bone level (CBL) on the mesial side; (4) CBL on the distal side; (5) first bone-to-implant contact (F-BIC) on the mesial side; (6) F-BIC on the distal side; (7) crown length; (8) implant length.

length groups (2.81%, 46.34%, and 95.83% for implants 8.0 mm, 6.0 mm, and 5.0 mm in length, respectively).

The implants' distribution was analyzed according to length definition (8.0 mm, 6.0 mm, and 5.0 mm). The overall descriptive statistics for the study variables are presented in Table 1.

Implant survival

At the uncovering stage, all the implants were osseointegrated, and no early failures were detected. Five implants were lost after functional loading (late failures due to excessive bone loss), in 5 different patients, all with a history of periodontal disease. One failure occurred in a 4.0 × 8.0 mm implant, two in 4.5 × 6.0 mm implants, and two in 5.0 × 5.0 mm implants. The failed implants' features are recorded in Table 2.

The overall proportion of implant survival at the 36-month follow-up was 97.51% (95% CI: 0.94–0.98), with no statistically significant differences ($P = .73$) between length groups: 98.59% (70/71), 97.56% (80/82), and 95.83% (46/48) for implants 8.0 mm, 6.0 mm, and 5.0 mm in length, respectively. No association was found between survival and failure groups, nor in any of the considered covariates (Table 3).

Crestal bone levels and peri-implant bone loss

Mean CBL at loading (t_0) was 1.89 ± 1.29 mm (range -2.45; 5.59); mean CBL at follow-up (t_1) was 1.32 ± 1.31 mm (range −3.59; 4.68). Mean ΔCBL was -0.4 ± 0.95 mm.

Mean F-BIC at loading (t_0) was 0.32 ± 0.72 mm (range 0; 3); mean F-BIC at follow-up (t_1) was 0.49 ± 0.72 mm (range 0; 4.13). Mean ΔF-BIC was 0.1 ± 0.62 mm.

ΔCBL and ΔF-BIC (Tables 4 and 5) were compared by one-way non-parametric ANOVA with each covariate as a between-patients factor. A statistically greater crestal bone loss (ΔCBL) for implants placed in premolar sites compared with those placed in molar sites was evident; there was also a statistically greater apical shift of the F-BIC (ΔF-BIC) for implants restored with resin crowns and for implants placed in patients with a history of periodontal disease. Crestal bone-level variations were not statistically different between length groups at the 3-year follow-up evaluation (Tables 4 and 5).

Discussion

Short implants were historically associated with a lower proportion of survival and unpredictable long-term outcomes.[10,11,16,19] Nevertheless, scientific evidence of the last decade has suggested similar implant survival for short and standard implants,[47] and proposed the use of short implants as a valid alternative to bone augmentation procedures, as well as the use of longer implants in sites characterized by compromised ridges.[48,49] Furthermore, improvements in implant-abutment connection design and surface textures led to considerably increased survival for implants 8.0 mm in length supporting single crowns.

Fugazzotto et al,[21] in a long-term retrospective study on endosseous implants less than 10 mm in length, found an implant survival of 98.4% for 315 standard-neck implants placed in the posterior mandible and restored with single crowns. Lai et al,[5] in a clinical retrospective study with 5 to 10 years of follow-up on 231 implants with an intra-bony length ≤8.0 mm, supporting single crowns, and placed in the posterior regions, found an overall survival of 98.3%; the survival for 198 implants 8.0 mm in length was 98.5% and the survival for 121 implants placed in the posterior mandible was 98.3%. Urdaneta et al[20] analyzed 199 implants 8.00 mm in length, mostly supporting single crowns, for an average follow-up of 20 months, and reported a survival of 95.2%. Mangano et al,[1] in a prospective study with 1 to 10 years of follow-up on 91 single-crown, locking-taper implants 8.0 mm in length and placed in the posterior mandible, reported an implant survival of 98.9%.

In the present retrospective study with a 3-year follow-up, we reported a proportion of implant survival of 98.59% for 71 implants 8.0 mm in length, with non-splinted single crown restorations, and placed in the posterior mandible; therefore, our results are in agreement with data previously reported in the literature.[1,5,20,21]

A meta-analysis by Srinivasan et al[22] indicated that short implants 6.0 mm in length can be used as a successful treatment option in the posterior jaw. Several other authors recently endorsed the use of implants 6.0 mm in length to support single crowns in daily clinical practice. Rossi et al[23] studied 40 implants 6.0 mm in length, with moderately rough surfaces, supporting single crowns, and placed in the posterior regions, and reported a survival of 95% after 2 years. Urdaneta et al[20] reported a survival of 97.6% for 211 implants shorter than 8.0 mm, placed in the maxilla and mandible, and mostly supporting single-crowns, with an average follow-up of 20 months. Lai et al[5] reported a survival of 97% for 33 implants 6.0 mm in length with 5 to 10 years of follow-up.

In the present study, after monitoring 82 mandibular implants 6.0 mm in length, we found a survival of 97.56% at 36 months. The data presented in this paper, together with a review of the current scientific research, seems to support the

Table 1

Overall placed implants: length-group distribution according to study variables*†

Variable	8 mm	6 mm	5 mm	Test Statistic	DF	*P* Value
Sex						
Male	23 (32.39)	48 (58.54)	15 (31.25)	$\chi^2 = 14.05$	2	$P < .001$
Female	48 (67.61)	34 (41.46)	33 (68.75)			
Age at follow-up	57.91 ± 12.86	59.12 ± 9.67	56.83 ± 9.07	$\chi^2 = 1.88$	2	$P = .38$
Smoking history						
No	54 (76.06)	68 (82.93)	41 (85.42)	$\chi^2 = 1.94$	2	$P = .37$
Yes	17 (23.94)	14 (17.07)	7 (14.58)			
ASA status						
I	35 (49.3)	39 (47.56)	29 (60.42)	$\chi^2 = 6.01$	4	$P = .20$
II	22 (30.98)	33 (40.24)	16 (33.33)			
III	14 (19.72)	10 (12.2)	3 (6.25)			
Oral professional hygiene/y	3.94 ± 0.95	3.68 ± 1.37	3.97 ± 1.06	$F = 1.36$	2/198	$P = .25$
History of periodontal disease						
No	22 (30.99)	22 (26.83)	6 (12.50)	$\chi^2 = 5.51$	2	$P = .06$
Yes	49 (69.01)	60 (73.17)	42 (87.50)			
Implant tooth site						
Premolar	32 (45.07)	22 (26.83)	23 (47.92)	$\chi^2 = 7.82$	2	$P = .02$
Molar	39 (54.93)	60 (73.17)	25 (52.08)			
Implant diameter						
4	32 (45.07)	33 (40.24)	3 (6.25)	$\chi^2 = 2.53$	6	$P = .45$
4.5	25 (35.21)	35 (42.68)	6 (12.50)			
5	11 (15.50)	12 (14.64)	30 (62.50)			
6	3 (4.22)	2 (2.44)	9 (18.75)			
Prosthetic material						
Resin	6 (8.45)	8 (9.76)	7 (14.58)	$\chi^2 = 3.46$	2	$P = .54$
Porcelain	65 (91.55)	74 (90.24)	41 (85.42)			
Crown-to-implant ratio						
>2	2 (2.81)	38 (46.34)	46 (95.83)	$\chi^2 = 123.72$	2	$P < .001$
<2	69 (97.18)	44 (53.65)	2 (4.16)			

*DF indicates degrees of freedom; ASA, American Society of Anesthesiologists.

†Age at follow-up and oral professional hygiene/y are presented as mean ± standard deviation; for all other variables, values are presented as n (%); significance level is set at 0.05.

use of single-crown implants 6.0 mm in length in daily clinical practice.

Nevertheless, these assumptions must be taken cautiously, especially considering our mid-term (3 years) follow-up. In a comparison, Rossi et al[50] reported an implant survival of 86.7% and 96.7% for implants 6.0 mm and 10 mm in length, respectively, supporting single-crowns with a 5-year follow-up. A recent prospective study by Naenni et al[51] showed a significantly different survival: 100% and 91% for implants 10 mm and 6.0 mm in length, respectively, supporting single crowns after 5 years of loading.

In a comprehensive systematic review, Mezzomo et al[26] evaluated the prognosis of implants shorter than 10 mm supporting single crowns (eg, implants 6.0 mm and 8.0 mm in length) and found no differences demonstrated. The authors claimed that evidence of long-term prognosis is still lacking. Considering a greater number of studies with longer follow-up, it was also postulated that the meta-regression analysis should have given different results, including a statistically significant different survival between implants 6.0 mm and 8.0 mm in length.

In a 3-year follow-up study by Clelland et al,[25] single-crown implants were compared with contralateral splinted-crown implants. A lower survival was found for single implants 6.0 mm

Table 2

Failure features*

Site	#31	#29	#30	#21	#28
Diameter	5	4.5	5	4.5	4
Length	5	6	5	6	8
Sex	Female	Male	Male	Male	Male
Smoking history	No	No	No	Yes	No
ASA status	III	I	I	II	III
Oral professional hygiene/y	4	3	4	3	4
History of periodontal disease	Yes	Yes	Yes	Yes	Yes
Crown-to-implant ratio	2.33	2.10	3.19	2.23	1.52

*ASA indicates American Society of Anesthesiologists.

TABLE 3

Analysis of implant survival according to included study covariates*†

Variable	Survival n (%)	Failure n (%)	χ^2	DF	*P* Value
Sex					
Male	82 (95.35)	4 (4.65)	2.9	1	$P = .10$
Female	114 (99.13)	1 (0.87)			
Smoking history					
No	159 (97.55)	4 (2.45)	0.004	1	$P = .65$
Yes	37 (97.37)	1 (2.63)			
History of periodontal disease					
No	50 (100)	0 (0.00)	1.69	1	$P = .23$
Yes	146 (96.69)	5 (3.31)			
Implant tooth site					
Premolar	74 (96.10)	3 (3.90)	1.02	1	$P = .28$
Molar	122 (98.39)	2 (1.61)			
Implant length					
8 mm	70 (98.59)	1 (1.41)	0.89	2	$P = .73$
6 mm	80 (97.56)	2 (2.44)			
5 mm	46 (95.83)	2 (4.17)			
Prosthetic material					
Resin	21 (100)	0 (0.00)	0.59	1	$P = .57$
Porcelain	175 (97.22)	5 (2.78)			
Crown-to-implant ratio					
>2	82 (95.35)	4 (4.65)	2.9	1	$P = .10$
<2	114 (99.13)	1 (0.87)			

*DF indicates degrees of freedom.

†For all variables, values are presented as n (%); significance level is set at 0.05.

in length compared to those of splinted crowns. Even if splinting was demonstrated by these authors to be a positive factor for the success of short implants 6.0 mm in length, a single-crown restoration is otherwise considered the preferred prosthetic approach,[45] due to its better emergence profiles and optimal acceptance by patients because of its easy maintenance with oral hygiene homecare.

Heterogeneity in the study design of different investigations discussed in the literature concerning implants 5.0 mm in length does not allow for definitive conclusions. Furthermore, RCTs on implants 5.0 mm in length supporting single crowns are currently scarce, and the majority of scientific evidence for implants 5.0 mm in length and placed in the posterior mandible concerns splinted implants.

A retrospective study of sintered porous-surfaced (SPS) implants with 1 to 8 years of follow-up [27] reported a survival of

TABLE 4

Crestal bone level (CBL) distribution and analysis of average bone loss (ΔCBL) according to included study covariates*†

Variable	CBL		ΔCBL		Test Statistic	DF	*P* Value
	Loading time Mean ± SD	Follow-up time Mean ± SD	Median	IQR			
History of periodontal disease							
No	2.34 ± 1.10	1.88 ± 1.01	−0.21	0.87	Z = 1.48		$P = .13$
Yes	1.74 ± 1.32	1.13 ± 1.35	−0.49	1.03			
Implant length							
8 mm	1.74 ± 1.29	1.12 ± 1.30	−0.55	1.11	$\chi^2 = 2.28$		$P = .31$
6 mm	1.97 ± 1.34	1.53 ± 1.37	−0.34	0.97		2	
5 mm	1.97 ± 1.22	1.29 ± 1.21	−0.38	0.92			
Implant tooth type							
Premolar	1.81 ± 1.50	1.09 ± 1.51	−0.59	1.02	Z = −2.02		$P = .04$
Molar	1.93 ± 1.15	1.46 ± 1.16	−0.34	0.84			
Crown-to-implant ratio							
>2	2.11 ± 1.39	1.34 ± 1.36	−0.42	0.97	Z = 1.9		$P = .05$
<2	1.72 ± 1.19	1.31 ± 1.28	−0.39	1.01			
Prosthetic material							
Resin	1.68 ± 1.47	0.79 ± 1.52	−0.82	0.98	Z = −1.61		$P = .10$
Porcelain	1.91 ± 1.27	1.38 ± 1.28	−0.39	0.99			

*DF indicates degrees of freedom.

†CBL and its variations are presented as mean ± standard deviation or median [IQR]; significance level is set at 0.05

Table 5

First bone-to-implant contact (F-BIC) distribution and analysis of average apical shift of the F-BIC position (ΔF-BIC) according to included study covariates*†

	FBIC								
	Loading time		Follow-up time		ΔFBIC				
Variable	Median	IQR	Median	IQR	Median	IQR	Test Statistic	DF	*P* Value
History of periodontal disease									
No	0.29	0.55	0.19	0.61	0.00	0.25	$Z = -2.78$		$P < .001$
Yes	0.33	0.75	0.58	0.67	0.17	0.64			
Implant length									
8 mm	0.33	0.75	0.57	0.93	0.10	0.47	$\chi^2 = 2.02$	2	$P = .36$
6 mm	0.34	0.72	0.42	0.77	0.06	0.58			
5 mm	0.23	0.60	0.50	0.68	0.19	0.66			
Implant tooth type									
Premolar	0.36	0.83	0.57	0.78	0.17	0.69	$Z = 1.16$		$P = .24$
Molar	0.28	0.63	0.44	0.80	0.07	0.54			
Crown-to-implant ratio									
>2	0.23	0.63	0.52	0.66	0.17	0.64	$Z = -1.66$		$P = .09$
<2	0.35	0.73	0.48	0.85	0.07	0.57			
Prosthetic material									
Resin	0.48	0.63	0.58	1.06	0.41	0.52	$Z = 2.32$		$P = .02$
Porcelain	0.30	0.72	0.48	0.82	0.07	0.59			

*DF indicates degrees of freedom.

†FBIC and its variations are presented as median [IQR]; significance level is set at 0.05.

100% for 12 ultra-short implants supporting single or fixed prostheses in the mandible. Similar survival were found in a 3-year randomized control trial [28] for splinted mandibular implants 5.0 mm in length compared to implants 10 mm in length, and in a 4-month randomized controlled trial, for splinted implants 4.0 mm in length compared to splinted implants 8.5 mm in length.[29] A 5-year prospective multicenter study on splinted implants 4.0 mm in length and placed in the posterior mandible found a survival of 92.2%.[24]

In our experience, 48 implants 5.0 mm in length and supporting single crowns, showed a survival of 95.83%, with no statistically significant differences when compared to implants 6.0 mm in length after 36 months.

Excessive bone loss after loading can influence implant survival. The threshold at which the clinical crown-to-implant ratios become excessive is still a controversial issue, especially regarding ultra-short implants. It has also been suggested that disproportionate prosthetic restorations with higher CIR could have a potential negative impact on mean peri-implant bone loss, and could reduce implant survival.[52] A study by Schulte et al[53] considered 889 locking-taper single crowns (410 in the mandible), and showed that the CIR was similar for surviving (1.3 ± 0.3) and failed (1.4 ± 2.5) implants, and that after an average of 2 years and 3 months of follow-up, there was no influence on the implant survival (98.2%). Urdaneta et al[42] postulated that an increased CIR (up to 4.95) does not have a statistically significant effect on the failure rate of single-tooth locking-taper plateau-design implants, but only 13 out of the 326 assessed implants were 6.0 mm in length. Malchiodi et al,[41] in a 3-year prospective study with 259 SPS splinted and single-crown implants (100 in the mandible and 159 in the maxilla), concluded that there was a statistical correlation between CIR and implant success or crestal bone loss; threshold values of 3.1 and 3.4 for anatomical and clinical CIR to avoid excessive tension on the abutment-bone interface were also suggested.

In our study, 48 locking-taper implants 5.0 mm in length showed a mean CIR of 2.71, which is comparable to the highest values found in the literature and yet, not negatively related to peri-implant bone loss. Bone levels stability (ΔCBL and ΔF-BIC) was indeed preserved after 3 years, without significant differences between implant CIR-groups (<2 and >2) and length groups.

There was a statistically greater apical shift of the F-BIC (ΔF-BIC) for implants restored with resin crowns, compared to those restored with porcelain crowns. However, there were no statistical differences between the 2 prosthetic materials as to implant survival or average bone loss (ΔCBL). Other authors[54–57] have also reported that they found no significant differences in terms of implant survival and marginal bone loss between resin and porcelain restorations. On the other hand, one author reported that reinforced composite resin material appears to accumulate more plaque deposits than titanium resulting in at least surface mucosal inflammation of peri-implant tissues.[58]

We hypothesize that there are possible confounding factors, such as a history of periodontal disease, that could have an important influence in determining this outcome, since implants placed in patients with a history of periodontal disease had a statistically increased ΔF-BIC. Moreover, this finding occurred in only one implant vs 20 implants in non-periodontal and periodontal patients, respectively.

It is also worth noting that the implant system examined in this study presents a screw-less locking-taper implant-abutment connection. Among others, the advantages of this connection include increased mechanical stability with no micromovements or micro gaps at the implant-abutment interface, thus leading to minimal bone resorption. The plateau

root-form implant design provides clinical capabilities different from threaded implants of the same size, eg, a 30% greater surface area, and unique Haversian bone formation and remodeling, which provides a more effective transference of the compressive forces to the bone throughout the entire implant.[59] Our results appear to be consistent with the findings of other authors who have experimented with this type of connection and implant design.[20,60]

However, this study presents some critical issues consequent to its retrospective nature and the mandibular area on which it was focused. Such issues include: the small sample size, the mid-term evaluation (3 years of follow-up), and a non-homogeneous distribution among implant length-groups. Additionally, the setting of a single-center (the University Dental Clinic) could also have introduced an important bias, which indicates that our results cannot be generalized.

On the other hand, a 1-year interval (January 2014–January 2015) for patient recruitment could be a favorable point in excluding any significant variations of technique.

Most of the patients enrolled in the study were characterized by a history of periodontal disease; this was potentially a critical limitation for the study, but it was not a significant issue for implant survival. Furthermore, all patients showed a positive compliance to the maintenance program.

Despite the limitations discussed already, the main strength of our study comprises a positive assessment: 3 years after loading, a high proportion of locking-taper implants 5.0 mm in length, restored with single crowns and having a moderately disproportionate crown-to-implant ratio, survived with stable crestal bone levels.

However, for the future, a prospective long-term (5-year follow-ups or longer) approach is necessary for a better evaluation of larger homogenous samples, with possible comparisons between mandibular and maxillary areas, as well as for a more balanced distribution between patients with or without a history of periodontal disease.

Conclusion

Short and ultra-short single-crown locking-taper implants used in this study have been demonstrated to be a successful treatment option in the atrophic posterior mandible.

However, further long-term investigations with major homogeneity in length-group distribution, multi-center patient recruitment, and a larger sample size are needed to corroborate our results on ultra-short implants in the mandible.

Abbreviations

ANOVA: analysis of variance
ASA: American Society of Anesthesiologists
CIR: crown-to-implant ratio
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
IAC: integrated abutment crown
IAI: implant-abutment interface
iqr: interquartile range

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