

ORIGINAL ARTICLE OPEN ACCESS

Clinical Outcomes of Bone-Level and Tissue-Level Short Implants Placed in Posterior Maxilla: A Case–Control Study

Teresa Lombardi¹ | Antonio Rapani²  | Fatima Ezeddine² | Giulia Perazzolo² | Roberto Di Lenarda² | Stefano Sivoilella³  | Claudio Stacchi² 

¹Department of Health Sciences, “Magna Græcia” University, Catanzaro, Italy | ²Department of Medical, Surgical and Health Sciences, University of Trieste, Trieste, Italy | ³Department of Neurosciences, University of Padova, Padova, Italy

Correspondence: Claudio Stacchi (claudio@stacchi.it)

Received: 25 August 2024 | **Revised:** 3 November 2024 | **Accepted:** 24 November 2024

Funding: The authors received no specific funding for this work.

Keywords: abutments | atrophic maxilla | crestal bone resorption | implant survival

ABSTRACT

Introduction: Short implants are today a reliable, minimally invasive option for the rehabilitation of the posterior maxilla. However, maintaining marginal bone stability remains a crucial factor for long-term success, particularly in the case of short implants. The present multicenter prospective case–control study aimed to compare the clinical outcomes of bone-level and tissue-level short implants in the posterior maxilla, focusing on implant survival and peri-implant marginal bone stability over 1 year of function.

Methods: Fifty-nine patients who met specific inclusion criteria were enrolled and treated by three clinical centers with a total of 74 short implants, either bone-level (7 mm in length, placed 1 mm sub-crestally) or tissue-level (5 or 6.5 mm in length). The primary outcome was physiological bone remodeling (PBR) measured via radiographs at baseline (T0), prosthesis delivery (T1), and 12 months post-loading (T2). Statistical analysis was performed to evaluate differences in PBR between groups, with multivariate analysis assessing the influence of various patient and site-specific factors.

Results: The final analysis included 58 patients who were treated with a total of 71 short implants, comprising 36 tissue-level and 35 bone-level implants (one patient dropped out as he did not attend follow-up visits on time). All implants were rehabilitated with fixed, screwed prosthetics after 5 months, with no recorded complications up to 1 year of loading. Stability was similar between the two implant types at T0 and T1, with no significant differences in insertion torque and implant stability quotient (ISQ). Multivariate analysis revealed a significant positive correlation between insertion torque and ISQ at T0, as well as with bicortical engagement of the implant apex with the sinus floor. Tissue-level implants demonstrated significantly lower peri-implant bone remodeling (PBR) compared to bone-level implants at both T1 (0.11 ± 0.27 mm vs. 0.34 ± 0.35 mm, $p = 0.004$) and T2 (0.30 ± 0.23 mm vs. 0.55 ± 0.42 mm, $p = 0.003$). Multivariate analysis showed a significant positive correlation between PBR (T0–T1) and thin vertical mucosal thickness (≤ 2 mm) at T0 in both tissue-level and bone-level implants. Additionally, PBR (T1–T2) in both groups significantly correlated with the use of short prosthetic abutments (≤ 2 mm) and, only in bone-level implants, with crown emergence angles $> 30^\circ$.

Conclusion: Both tissue-level and bone-level short implants are effective options for implant-supported rehabilitation in the posterior maxilla. Tissue-level short implants offer superior marginal bone stability compared to bone-level implants placed subcrestally, suggesting their favorable use in clinical practice.

This is an open access article under the terms of the [Creative Commons Attribution](https://creativecommons.org/licenses/by/4.0/) License, which permits use, distribution and reproduction in any medium, provided the original work is properly cited.

© 2024 The Author(s). *Clinical Implant Dentistry and Related Research* published by Wiley Periodicals LLC.

1 | Introduction

Implant-supported rehabilitation of the edentulous posterior maxilla may present challenging clinical difficulties due to the poor bone quality of the area, often associated with limited available bone height after post-extractive alveolar bone resorption and sinus pneumatization [1, 2]. Various surgical strategies are available to overcome these issues, including short and tilted implants, maxillary sinus floor elevation, vertical and horizontal augmentation of the atrophic bone crest, and pterygoid or zygomatic implants [3–9]. This broad range of therapeutic options should be thoroughly evaluated by the clinician, who should weigh the advantages and disadvantages of the various approaches in each individual patient.

Short implants are currently considered an interesting minimally invasive option also in the posterior maxilla [10]. Numerous recent clinical studies, systematic reviews, and meta-analyses reported comparable or even more favorable clinical outcomes for implants <8 mm when compared to standard-length implants associated with sinus augmentation procedures [3, 4, 11–14]. Moreover, short implants reduce patient morbidity, time of therapy, and economic costs [4, 10].

Stability of peri-implant marginal bone levels, which has always been considered among the most important parameters to evaluate implant success [15], is even more crucial when implant length is limited. Loss of crestal bone around short implants not only exposes the implant to a higher risk of peri-implant pathologies but may also represent a significant reduction of total implant bony support [16]. In particular, adequate control of physiological bone remodeling is fundamental to prevent further peri-implant bone loss and decrease the risk of peri-implant pathologies over time [17, 18]. However, it should be emphasized that this concept is mainly valid when using implants with treated surfaces. In fact, there are various studies in the literature that demonstrate how the physiological bone remodeling is not a predictor of further bone loss and/or implant failure when using machined implants [19–21].

Among the various factors potentially influencing physiological bone remodeling (insufficient bone envelope, traumatic surgery, excessive cortical compression during implant insertion, supracrestal tissue adhesion, prosthetic abutment height, number of abutment connections/disconnections, crown-implant ratio, and restoration emergence profile) [22–28], the microbial colonization of the implant-abutment micro-gap plays a paramount role [29, 30]. Bacterial harboring into the micro-gap induces local inflammation resulting in the formation of an area of infiltrated connective tissue that three-dimensionally surrounds the implant-abutment area, causing bone resorption [31].

Two main strategies have been developed to overcome this issue: improvement of the quality of implant-abutment connections and the introduction of horizontal implant-abutment mismatch (platform-switching) to move micro-gap location far from the bone crest. Internal and, in particular, conical connections allow a considerable reduction of micro-gap dimensions when compared to flat-to-flat configuration (5–10 vs. 30–50 μ m), limiting at the same time unwanted micro-movements at the connection level under loading conditions [32]. Platform-switching

has also demonstrated to be an efficient strategy to limit peri-implant bone resorption, provided that the distance between the micro-gap and the bone crest is ≥ 0.4 mm [33].

Tissue-level implants, in which the implant-abutment junction is coronally displaced far from the bone crest, showed long-term, extremely positive outcomes in terms of marginal bone preservation and connection stability [34]. However, a broader use in the clinical practice of tissue-level implants has been hampered by some intrinsic limitations: the main drawback of this implant configuration is related to possible esthetic issues in case of thin supracrestal tissue height and/or soft tissue recessions.

To the best of the authors' knowledge, no comparative studies are present in the literature on the clinical outcomes of bone-level and tissue-level short implants when used in the rehabilitation of the posterior maxilla. Therefore, the aim of the present multicenter prospective case-control study is to compare implant survival and marginal bone stability of bone-level and tissue-level short implants placed in the posterior maxilla and followed for 1 year after prosthetic loading.

2 | Materials and Methods

2.1 | Study Design

The present study was designed as a multicenter, prospective case-control study, conducted by three experienced operators (T.L., S.S., C.S.), who enrolled and treated patients from June 2020 to May 2023. The present investigation follows the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines. The study protocol adheres to the recommendations of the Fortaleza revision (2013) of the Helsinki Declaration for research on human subjects and was approved by the Comitato Etico Regione Calabria—Sezione Area Centro (n. 194/2020 dd. 18/06/2020). The study was recorded in a public registry of clinical studies (<https://clinicaltrials.gov>—no. NCT05975138). The three clinical centers participated in a calibration meeting prior to the beginning of the study to standardize operative procedures and data collection, with the aim of reaching acceptable inter-operator consistency.

All patients were thoroughly informed about the study protocol, the therapeutic program with associated possible risks, and viable alternatives. Patients willing to participate in this study signed a written informed consent and authorized the use of their clinical and personal data for research purposes.

The present superiority trial tested the null hypothesis of no difference in peri-implant marginal bone loss after 1 year of function around tissue-level (test group) and bone-level (control group) short implants inserted in the posterior maxilla against the alternative hypothesis of a difference.

2.2 | Patient Selection

All partially edentulous patients needing an implant-supported rehabilitation in pristine bone in the posterior maxilla were evaluated for potential inclusion in this case-control study.

General inclusion criteria were the following:

- I. age > 18 years;
- II. good general health conditions;
- III. no systemic diseases influencing osseous metabolism and/or wound healing;
- IV. no regular medication intake;
- V. patient able to comply with the study protocol;
- VI. signed informed consent.

Local inclusion criteria were the following:

- VII. edentulous alveolar ridge with a minimum of 6 mm width and 4.5–8.0 mm height between the alveolar crest and the maxillary sinus floor, with no concomitant or previous bone augmentation procedures;
- VIII. time from tooth loss/extraction > 6 months;
- IX. absence of any removable prosthesis in the planned treatment area;
- X. presence of opposing dentition.

Exclusion criteria were:

- I. general contraindications to implant surgery [35];
- II. glycated hemoglobin > 7.5%;
- III. present or past treatment with antiresorptive drugs;
- IV. pregnancy or breastfeeding;
- V. full mouth plaque score (FMPS) > 25%;
- VI. untreated periodontal disease;
- VII. substance abuse
- VIII. insertion torque < 20 Ncm.

All patients were motivated for oral hygiene and underwent professional deplaquing 1 week before surgery.

A total of 59 consecutive patients who met the study inclusion criteria were recruited from three clinical centers (T.L.: 19; S.S.: 15; C.S.: 25) and treated with the insertion of 74 short implants, consisting of 37 tissue-level and 37 bone-level implants. All implants were placed with a one-stage protocol and were rehabilitated with fixed prosthetics 5 months after placement.

The demographic characteristics of these patients are presented in Table 1.

2.3 | Clinical Procedures

After raising a minimally invasive full-thickness buccal flap under local anesthesia (articaine 4% with epinephrine 1:100000), supracrestal tissue height was measured with a periodontal probe (UNC 15, Hu-Friedy, Chicago, USA) and categorized into thin (≤ 2 mm) or thick (> 2 mm) biotype [36]. After completing

TABLE 1 | Demographic characteristics of the treated patients.

	Total (n = 59)
Age	64.1 ± 10.9
Gender (male/female)	26 (44.1%)/33 (55.9%)
Smoking habits (yes/no)	12 (20.3%)/47 (79.7%)
History of periodontitis (yes/no)	18 (30.5%)/41 (69.5%)



FIGURE 1 | Short implants (M2, Zeros, Busan, South Korea) used in the present study. Left to right: 7-mm-length bone-level implant; 5-mm-length tissue-level implant; 6.5-mm-length tissue-level implant.

palatal flap elevation, the implant site was prepared with rotary instruments under abundant irrigation to allow placement of a 4-mm-diameter short implant (M2, Zeros, Busan, South Korea) with a conical hybrid connection. The most appropriate implant length (5, 6.5, or 7 mm) was chosen by the surgeon based on the available bone height below the sinus floor. A 5- and 6.5-mm-length fixtures are tissue-level implants with a 2 mm high, machined, convergent trans-epithelial neck, with the rest of the fixture presenting a moderately rough titanium surface. A 7-mm-length implant is a bone-level implant fully treated with a moderately rough surface (Figure 1). Tissue-level and bone-level implants, excluding the neck area, present the same macro-morphology and connection. As per the manufacturer's recommendations, tissue-level implants were placed with the rough surface submerged in the bone and the neck at soft tissue level for transgingival healing, while bone-level implants were positioned 1 mm subcrestally and immediately connected to a healing abutment.

Insertion torque (IT) was recorded by the surgical motor (Implantmed, W&H, Bürmoos, Austria) and implant stability quotient (ISQ) was measured after implant placement with a specific transducer (Smartpeg #27, Osstell, Göteborg, Sweden). Flaps were sutured in both groups for an unsubmerged healing with single sutures and/or the Sentineri technique using synthetic monofilament [37]. Antibiotic therapy (amoxicillin/clavulanate 1 g twice a day) for 5 days and nonsteroidal anti-inflammatory drugs (ketoprofen 80 mg when needed) were prescribed. Sutures were removed after 12 days, and the course of healing was checked monthly.

After 4 months of healing, ISQ was measured and definitive impressions were taken. Screwed metal-ceramic single crowns or three-unit bridges were delivered, and patients entered into a 4-month recall program to check and maintain oral hygiene standards.

2.4 | Radiographic Measurements

Periapical radiographs were taken using a long-cone paralleling technique with a customized Rinn-type film holder at implant placement (T0), at prosthesis delivery (5 months after implant placement—T1), and after 12 months of function (T2) (Figures 2 and 3).

Variations in peri-implant bone levels using T0 as a reference point were measured at each time interval on both the mesial and distal aspects of the implant. A positive value was assigned when bone level was more coronal than at T0, whereas a negative value was assigned when bone level was more apical than at T0.

All measurements were taken by two calibrated examiners (F.E. and G.P.) on a 28-in. diagnostic monitor using measuring software (Image J 1.52a, National Institutes of Health, Bethesda, USA). Measurements were calibrated referring to the known implant diameter at platform level. Each measurement was taken three times at three different time points, as previously proposed by Gomez-Roman and Launer [38]. Examiners were calibrated by assessing 12 radiographs, with a different assessor (S.S.) serving as a reference examiner. Intraclass correlation

coefficients to assess intra-observer and inter-observer variability were 0.99 and 0.87, respectively, for linear measurements within ± 0.1 mm.

Moreover, crown-implant ratio and interproximal crown emergence angles (mesial and distal) were measured on T1 radiographs using the same software. According to the Glossary of Prosthodontic Terms, emergence angle was defined as “the angle of an implant restoration’s transitional contour as determined by the relation of the surface of the abutment to the long axis of the implant body” [39].

2.5 | Predictor and Outcome Variables

Primary site-specific predictor variables were the following: (i) crestal vertical mucosal thickness (thick > 2 mm vs. thin ≤ 2 mm) [40, 41]; (ii) implant insertion torque (> 50 vs. ≤ 50 Ncm) [42, 43]; (iii) implant primary stability (≥ 60 vs. < 60 ISQ) [44]; (iv) bicortical engagement of the implant on the sinus floor (yes/no) [45]; (v) abutment height (long > 2 mm vs. short ≤ 2 mm) [25, 46]; (vi) crown-implant ratio [27]; (vii) crown emergence angle ($> 30^\circ$ vs. $\leq 30^\circ$) [28, 47]. The possible influence on the primary outcome of the following patient-related variables was also analyzed: (i) age; (ii) gender; (iii) smoking habits (smoker vs. non smoker); (iv) history of periodontitis (yes/no).

Primary outcome (dependent variables):

- physiological bone remodeling (PBR) at T1 and T2.

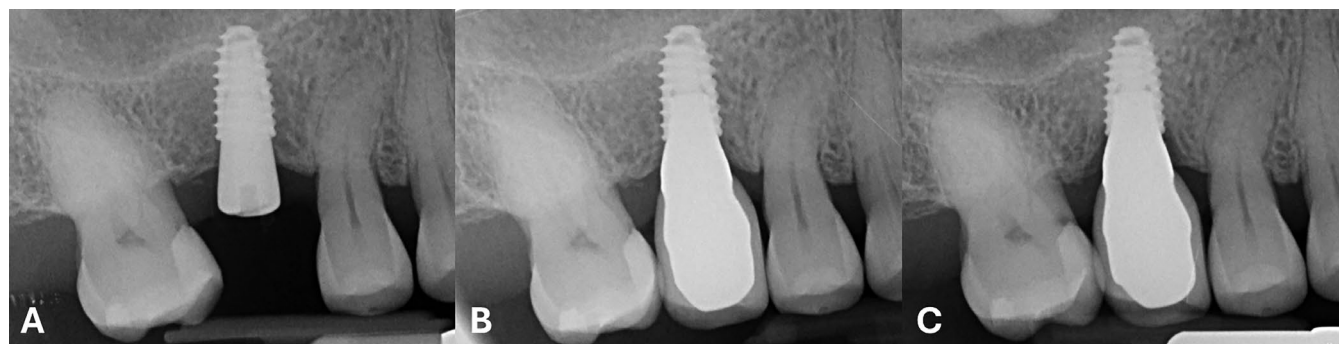


FIGURE 2 | Bone-level implant at implant positioning (A), crown delivery (B), and after 12 months of loading (C).

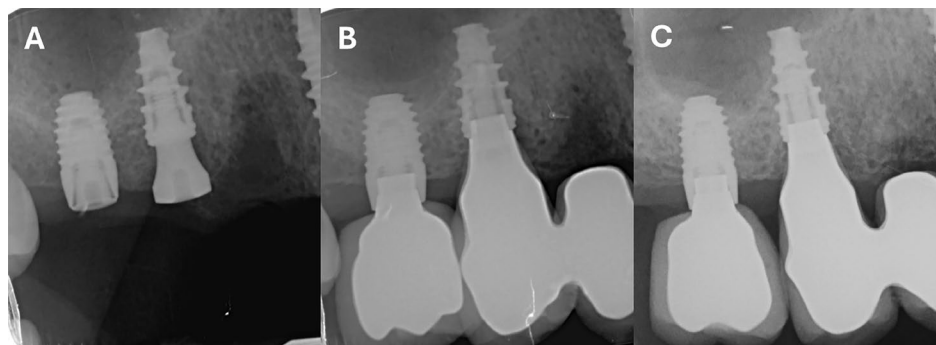


FIGURE 3 | Tissue-level implant at implant positioning (A), crown delivery (B), and after 12 months of loading (C).

Secondary outcomes:

- implant stability at T0 (peak insertion torque; ISQ);
- implant failure (implant mobility or implant removal due to progressive marginal bone loss);
- any biological or mechanical complication.

2.6 | Sample Size Calculation and Statistical Power

The sample size of the present prospective study was calculated using a statistical software (Primer of Biostatistics 6.0, McGraw-Hill Education, New York, USA), based on data reported in a previous publication on peri-implant marginal bone level variations between bone-level and tissue-level implants after 1 year of function (-0.03 ± 0.74 and 0.26 ± 0.55 mm, respectively) [48]. A sample of 34 implants for each group was required to detect significant differences between the two groups (confidence level 5% with statistical power of 80%).

2.7 | Statistical Analysis

Statistical analysis was performed by an independent assessor (A.R.) using IBM SPSS Statistics Version 26.0 software (IBM, Armonk, NY, USA). Descriptive statistics for continuous variables were presented as means and standard deviations for parametric data or as medians and interquartile ranges for non-parametric data, while categorical variables were expressed as frequencies. The Shapiro–Wilk test was used to assess the distribution of the dataset at various time points, and the Levene test was applied to evaluate the equality of variances. Differences in continuous variables between the test and control groups were analyzed using a *t*-test for parametric data and a two-sample Wilcoxon rank-sum test for non-parametric data. Multiple linear regression analysis was performed to assess the impact of independent variables on the dependent variable. The “Enter” method was used to include all independent variables in the model. A *p*-value of less than 0.05 was considered statistically significant.

3 | Results

One patient, who received three implants (one 5 mm tissue-level implant and two 7 mm bone-level implants), was lost to follow-up after prosthetic delivery, as he was no longer interested in participating in the study.

Therefore, the final analysis included 58 patients (25 men and 33 women, mean age 63.3 ± 11.3 years) who received 36 tissue-level implants [5 mm length ($n = 18$) or 6.5 mm length ($n = 18$)] and 35 bone-level implants (7 mm length), supporting 67 single crowns and 2 three-unit bridges. Among patients included in the final analysis, 13 patients received two implants (one tissue-level – 5.0 or 6.5– and one bone-level – 7 mm) and 45 patients received a single implant.

The mean residual bone height between the alveolar crest and the floor of the maxillary sinus at the time of implant placement was 6.2 ± 2.3 mm. No complications or adverse events were

recorded and after 1 year of prosthetic loading, all 71 implants were satisfactorily in function.

At T0, no significant differences in primary stability were observed between bone-level and tissue-level implants, either in terms of mean IT (bone-level: 40.8 ± 11.3 Ncm; tissue-level: 41.9 ± 14.0 Ncm; $p = 0.56$) or mean ISQ (bone-level: 64.7 ± 10.3 ; tissue-level: 66.8 ± 9.3 ; $p = 0.42$). Similarly, at T1, implant stability (ISQ) did not differ significantly between the two groups (bone-level: 71.4 ± 6.5 ; tissue-level: 69.5 ± 7.0 ; $p = 0.10$). Multivariate analysis revealed a significant positive correlation between IT and ISQ (T0). Additionally, IT showed a significant positive correlation with bicortical engagement of the implant apex in the sinus floor.

Mesial and distal PBR values at T1 and T2 were compared using a paired *t*-test, which revealed no significant differences. Therefore, the average of mesial and distal PBR was used as the primary outcome in the subsequent analysis. Mean PBR (T0–T1) around tissue-level implants (0.11 ± 0.27 mm) was significantly lower than around bone-level implants (0.34 ± 0.35 mm) ($p = 0.004$). Similarly, mean PBR (T0–T2) around tissue-level implants (0.30 ± 0.23 mm) remained significantly lower than around bone-level implants (0.55 ± 0.42 mm) ($p = 0.003$).

Multivariate analyses revealed a significant positive correlation between PBR (T0–T1) and vertical mucosal thickness ≤ 2 mm in both tissue-level and bone-level implants. However, no significant associations were found between PBR (T0–T1) and other possible influencing factors such as age, gender, smoking habits, history of periodontitis, peak insertion torque > 50 Ncm, ISQ (T0) ≥ 60 , or bicortical engagement of the implant apex in the cortical of the sinus floor (Tables 2 and 3).

In tissue-level implants, PBR (T1–T2) showed a significant positive correlation with the presence of a short prosthetic abutment (≤ 2 mm). No significant associations were found with age, gender, smoking habits, history of periodontitis, crown–implant ratio, or emergence profile angle of the crown $> 30^\circ$ (Tables 4 and 5). In bone-level implants, PBR (T1–T2) showed a significant positive correlation with both the presence of a short prosthetic abutment (≤ 2 mm) and the emergence profile angle of the crown $> 30^\circ$. No significant associations were found with age, gender, smoking habits, history of periodontitis, or crown–implant ratio (Tables 6 and 7).

4 | Discussion

The present multicenter, prospective case–control study aimed to evaluate and compare the clinical outcomes of tissue-level and bone-level short implants in the rehabilitation of the posterior maxilla, focusing on implant survival and peri-implant marginal bone stability after 1 year of functional loading.

4.1 | Implant Survival and Stability

The present study demonstrated high implant survival rates for both tissue-level and bone-level short implants, with all 71 implants remaining in function after 1 year. This finding aligns

TABLE 2 | Multiple linear regression analysis to assess the impact of independent variables on the dependent variable PBR (T0–T1) of tissue-level implants.

	Coefficient <i>B</i>	95% CI	<i>p</i> -value
Gender			
Male	1		
Female	−0.001	[−0.182 to 0.180]	0.992
Age	0.003	[−0.005 to 0.011]	0.461
Smoking habits			
Yes	1		
No	0.066	[−0.137 to 0.270]	0.508
History of periodontitis			
Yes	1		
No	0.118	[−0.088 to 0.323]	0.250
Bicorticalism			
Yes	1		
No	−0.066	[−0.218 to 0.086]	0.380
Insertion torque			
> 50 Ncm	1		
≤ 50 Ncm	0.061	[−0.142 to 0.263]	0.543
ISQ (T0)			
≥ 60	1		
< 60	0.058	[−0.148 to 0.263]	0.570
Mucosal thickness			
Thick (> 2 mm)	1		
Thin (≤ 2 mm)	−0.410	[−0.578 to −0.241]	0.000 *

*Statistically significant.

Abbreviations: CI, confidence interval; ISQ, implant stability quotient.

with existing literature that supports the use of short implants as a viable solution in cases of reduced bone height in the posterior maxilla. Recent randomized clinical trials with 10-year follow-up [49, 50], along with meta-analyses [3, 4, 11–14], indicate that short implants demonstrate equal or superior long-term performance compared to standard implants combined with

TABLE 3 | Multiple linear regression analysis to assess the impact of independent variables on the dependent variable PBR (T0–T1) of bone-level implants.

	Coefficient <i>B</i>	95% CI	<i>p</i> -value
Gender			
Male	1		
Female	−0.160	[−0.368 to 0.048]	0.127
Age	−0.008	[−0.017 to 0.001]	0.095
Smoking habits			
Yes	1		
No	0.241	[−0.013 to 0.496]	0.062
History of periodontitis			
Yes	1		
No	0.075	[−0.188 to 0.337]	0.564
Bicorticalism			
Yes	1		
No	0.008	[−0.207 to 0.223]	0.936
Insertion torque			
> 50 Ncm	1		
≤ 50 Ncm	−0.071	[−0.350 to 0.208]	0.605
ISQ (T0)			
≥ 60	1		
< 60	0.122	[−0.129 to 0.372]	0.327
Mucosal thickness			
Thick (> 2 mm)	1		
Thin (≤ 2 mm)	−0.480	[−0.685 to −0.275]	0.000 *

*Statistically significant.

Abbreviations: CI, confidence interval; ISQ, implant stability quotient.

sinus floor elevation in terms of implant survival, marginal bone loss, and incidence of intra- and post-operative complications.

Surface treatment and implant morphology are two essential factors for achieving predictable success with short implants. The

TABLE 4 | Multiple linear regression analysis to assess the impact of independent variables on the dependent variable PBR (T1–T2) on the mesial aspect of tissue-level implants.

	Coefficient <i>B</i>	95% CI	<i>p</i> -value
Gender			
Male	1		
Female	−0.032	[−0.191 to 0.128]	0.687
Age	0.005	[−0.003 to 0.012]	0.232
Smoking habits			
Yes	1		
No	0.164	[−0.034 to 0.363]	0.101
History of periodontitis			
Yes	1		
No	−0.161	[−0.363 to 0.040]	0.112
Crown/implant ratio	−0.121	[−0.359 to 0.118]	0.310
Abutment height			
Long (> 2 mm)	1		
Short (≤ 2 mm)	−0.195	[−0.337 to −0.053]	0.009*
Mesial emergence angle			
≤ 30°	1		
> 30°	0.000	[−0.007 to 0.008]	0.941

*Statistically significant.
Abbreviation: CI, confidence interval.

use of moderately rough surfaces (S_a between 1 and 2 μm) allows for a significant increase in the bone–implant contact area, even with limited implant lengths, greatly impacting the success of the treatment. It is worth noting that studies conducted on short implants with minimally rough surfaces (S_a between 0.5 and 1 μm) placed in the posterior maxilla reported a failure rate of around 20% at 5 years [51–54]. On the other hand, implant morphology must ensure predictable primary stability, even with a reduced fixture length in poor-quality bone. Tapered design, increased diameter, and deep threads are features that help enhance the primary stability of an implant, all other conditions being equal [55]. The implants used in the present study present these characteristics, and the fixture morphology is identical in both the bone-level and tissue-level configurations. In fact, no

TABLE 5 | Multiple linear regression analysis to assess the impact of independent variables on the dependent variable PBR (T1–T2) on the distal aspect of tissue-level implants.

	Coefficient <i>B</i>	95% CI	<i>p</i> -value
Gender			
Male	1		
Female	0.015	[−0.200 to 0.229]	0.891
Age	0.009	[0.000 to 0.019]	0.058
Smoking habits			
Yes	1		
No	0.056	[−0.240 to 0.351]	0.703
History of periodontitis			
Yes	1		
No	−0.163	[−0.425 to 0.098]	0.211
Crown/implant ratio	0.002	[−0.347 to 0.351]	0.990
Abutment height			
Long (> 2 mm)	1		
Short (≤ 2 mm)	−0.253	[−0.470 to −0.035]	0.024 *
Distal emergence angle			
≤ 30°	1		
> 30°	0.010	[−0.006 to 0.025]	0.205

*Statistically significant.
Abbreviation: CI, confidence interval.

significant differences were observed in terms of primary stability between bone-level and tissue-level implants, whether considering insertion torque or the implant stability quotient (ISQ). It should be emphasized that the multivariate analysis revealed a positive correlation between primary stability and bicortical engagement of the implant apex with the maxillary sinus floor. This finding is consistent with previous in vitro and clinical studies [45, 56] and should be carefully considered, especially in cases of poor-quality bone and limited height. Bicortical anchorage helps to reduce tensile stress distribution at the crestal cortical level [57], significantly improving the mid-term prognosis of short implants in the posterior maxilla [58]. Moreover, when performed following a strict protocol, it does not pose a risk to the health or homeostasis of the maxillary sinus [59].

TABLE 6 | Multiple linear regression analysis to assess the impact of independent variables on the dependent variable PBR (T1–T2) on the mesial aspect of bone-level implants.

	Coefficient <i>B</i>	95% CI	<i>p</i> -value
Gender			
Male	1		
Female	0.047	[−0.087 to 0.181]	0.477
Age	0.005	[−0.002 to 0.011]	0.166
Smoking habits			
Yes	1		
No	−0.053	[−0.207 to 0.101]	0.486
History of periodontitis			
Yes	1		
No	−0.040	[−0.221 to 0.142]	0.658
Crown/implant ratio	−0.012	[−0.192 to 0.169]	0.896
Abutment height			
Long (> 2 mm)	1		
Short (≤ 2 mm)	−0.302	[−0.576 to −0.132]	0.038*
Mesial emergence angle			
≤ 30°	1		
> 30°	0.014	[0.002 to 0.026]	0.019*

*Statistically significant.
Abbreviation: CI, confidence interval.

TABLE 7 | Multiple linear regression analysis to assess the impact of independent variables on the dependent variable PBR (T1–T2) on the distal aspect of bone-level implants.

	Coefficient <i>B</i>	95% CI	<i>p</i> -value
Gender			
Male	1		
Female	−0.105	[−0.254 to 0.044]	0.161
Age	0.002	[−0.005 to 0.008]	0.589
Smoking habits			
Yes	1		
No	−0.031	[−0.199 to 0.137]	0.707
History of periodontitis			
Yes	1		
No	−0.155	[−0.338 to 0.029]	0.096
Crown/implant ratio	0.099	[−0.098 to 0.296]	0.313
Abutment height			
Long (> 2 mm)	1		
Short (≤ 2 mm)	−0.277	[−0.515 to −0.097]	0.045*
Distal emergence angle			
≤ 30°	1		
> 30°	0.015	[0.005 to 0.024]	0.003*

*Statistically significant.
Abbreviation: CI, confidence interval.

4.2 | Peri-Implant Physiological Bone Remodeling

The primary outcome of the present study was the evaluation of physiological bone remodeling (PBR) up to 12 months of function, which is a critical indicator of implant success [15–18, 60], particularly in short implants where bone support is inherently limited. Nevertheless, the literature presents contrasting findings regarding the predictive value of PBR for the long-term success and survival of dental implants. Several studies suggest that early bone loss does not necessarily predict continued bone loss or implant failure [19–21]. Additionally, other studies have reported a negative correlation between cumulative marginal bone loss and

implant failure rates over extended periods (25–35 years of function), raising questions about the diagnostic reliability of bone level changes for assessing implant longevity [61, 62]. It is important to emphasize, however, that all the studies mentioned above were conducted with machined implants presenting minimally rough surfaces (S_a between 0.5 and 1 μm), whereas the implants in the present study have moderately rough surfaces (S_a between 1 and 2 μm). Long-term clinical studies and systematic reviews suggest that implant surface characteristics play a significant role in the progression and treatment outcomes of peri-implantitis, with machined implants exhibiting the least bone loss and achieving the most favorable treatment outcomes [63–65].

The results of the present study indicated that bone-level implants exhibited significantly greater mean PBR (T0–T1: 0.34 ± 0.35 mm; T0–T2: 0.55 ± 0.42 mm) compared to tissue-level implants (T0–T1: 0.11 ± 0.27 mm; T0–T2: 0.30 ± 0.23 mm). This can be attributed to the fact that, in the present study, all implants underwent unsubmerged healing, leading to immediate microbial colonization of the microgap between the implant and healing abutment [66, 67]. The presence of a microgap at bone level, regardless of the surgical approach, consistently results in a certain degree of crestal bone loss. This is driven by a predictable biological principle: Ericsson et al. [31] demonstrated that microbial colonization of the microgap triggers an inflammatory reaction, causing peri-implant bone resorption and the formation of an inflammatory cell infiltrate around the microgap. Hermann et al. [68] further showed that in all two-piece implant configurations, the extent of crestal bone loss was significantly affected by the microgap position relative to the bone crest. Significant bone loss and inflammation were observed when the microgap was at the bone crest level, while significantly less bone resorption and peri-implant inflammation occurred when the microgap was positioned 1 mm above the crest.

Multivariate analyses showed that peri-implant bone remodeling (PBR) from T0 to T1 in both tissue-level and bone-level implants was significantly associated with thin vertical mucosal thickness (≤ 2 mm). This finding aligns with several studies on the formation of supracrestal tissue adhesion around implants. Berglundh and Lindhe [69] were the first to observe that when the ridge mucosa was thin (≤ 2 mm) before abutment connection, wound healing consistently involved bone resorption. When an implant is exposed to the oral cavity, the soft tissue forms a protective barrier against bacterial infiltration into the underlying alveolar bone [70]. This process, known as supracrestal tissue adhesion [24], takes about 8 weeks for soft tissue maturation and results in the formation of a biological seal with an average vertical dimension in humans of 2.7 ± 0.4 mm (range 2.1–3.2 mm) [71]. If the vertical dimension of the peri-implant mucosa is insufficient to form an adequate supracrestal tissue adhesion, peri-implant marginal bone resorption occurs during healing to create additional space. This phenomenon has been well documented in numerous clinical studies [40, 41, 72–74]. Additionally, it is important to note that the average supracrestal tissue height around tissue-level implants in humans has been shown to be lower than that around bone-level implants [75].

During the subsequent period (T1–T2, from prosthesis delivery to 12 months of functional loading), multivariate analyses revealed a significant correlation between peri-implant bone remodeling (PBR) around both tissue-level and bone-level implants and the use of short prosthetic abutments (≤ 2 mm). This is in accordance with numerous clinical studies and meta-analyses reaching the same conclusions [25, 46, 76–80]. Possible explanations involve the encroachment of the crown into the space occupied by newly-formed supracrestal tissue and issues related to the microgap between the abutment and crown. In cases with a thin soft tissue phenotype, the use of a short abutment may result in insufficient vertical mucosal thickness, potentially hindering the maintenance of the proper dimensions for supracrestal tissue adhesion. Consequently, marginal bone loss may occur as an attempt to restore the necessary vertical space. In contrast, when a short abutment is

used in patients with a thick soft tissue phenotype, the crown-abutment microgap and associated inflammatory infiltrate are positioned closer to the bone crest, possibly contributing to increased bone resorption.

Finally, an emergence profile angle of the crown $> 30^\circ$ showed a significant positive correlation with PBR (T1–T2) in bone-level implants, but not in tissue-level implants. This aligns with findings from a previous cross-sectional study, which showed that a shallower emergence angle at interproximal sites may lower the risk of peri-implantitis for bone-level implants. In contrast, for tissue-level implants, the emergence angle does not appear to be linked to an increased prevalence of peri-implantitis [47]. The influence of prosthetic restoration emergence profile characteristics on PBR is indeed a highly debated topic. A recent meta-analysis on this subject, which includes only four studies, suggests that implant-supported crowns with an emergence angle $\leq 30^\circ$ are associated with less PBR compared to crowns with an emergence angle $> 30^\circ$ [81]. However, the authors emphasize that this finding should be interpreted with caution, as the evidence supporting the study's conclusions is limited.

4.3 | Study Limitations and Future Research

The present study presents several limitations that should be considered. The follow-up period was limited to 1 year, which, while adequate for observing physiological bone remodeling, may not capture long-term differences in implant performance. Furthermore, although the sample size was statistically sufficient, it was relatively small. Larger studies with extended follow-up periods are needed to validate these findings and examine other potential factors, such as the impact of occlusal loading patterns and prosthetic design over time.

Moreover, the bone-level implants were placed 1 mm subcrestally, following the manufacturer's recommendations. The optimal placement of the implant platform—whether at the crestal or sub-crestal level—remains a topic of debate, with clinical studies and meta-analyses showing conflicting results [74, 82–84]. Therefore, the differences in PBR observed in the present study may also be influenced by the subcrestal positioning of the implants.

Future research should also explore the long-term clinical outcomes of tissue-level versus bone-level short implants across different anatomical settings and patient populations to better generalize the results of this investigation.

5 | Conclusion

In conclusion, this study provides evidence that both tissue-level and bone-level short implants are effective options for implant-supported rehabilitation in the posterior maxilla, with high survival rates and excellent marginal bone stability after 1 year of loading. The choice of implant type should be tailored to the individual patient's clinical scenario, with careful consideration of mucosal thickness and other local factors to optimize peri-implant bone stability and long-term success.

Acknowledgments

Open access publishing facilitated by Università degli Studi di Trieste, as part of the Wiley - CRUI-CARE agreement.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

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

References

1. G. O. Gallucci, M. Avrampou, J. C. Taylor, J. Elpers, G. Thalji, and L. F. Cooper, "Maxillary Implant-Supported Fixed Prosthesis: A Survey of Reviews and Key Variables for Treatment Planning," *International Journal of Oral & Maxillofacial Implants* 31 (2016): s192–s197.
2. T. Lombardi, F. Bernardello, F. Berton, et al., "Efficacy of Alveolar Ridge Preservation After Maxillary Molar Extraction in Reducing Crestal Bone Resorption and Sinus Pneumatization: A Multicenter Prospective Case-Control Study," *BioMed Research International* 2018 (2018): 9352130.
3. O. Grunau and H. Terheyden, "Lateral Augmentation of the Sinus Floor Followed by Regular Implants Versus Short Implants in the Vertically Deficient Posterior Maxilla: A Systematic Review and Timewise Meta-Analysis of Randomized Studies," *International Journal of Oral and Maxillofacial Surgery* 52 (2023): 813–824.
4. A. Ravidà, I. C. Wang, G. Sammartino, et al., "Prosthetic Rehabilitation of the Posterior Atrophic Maxilla, Short (≤ 6 mm) or Long (≥ 10 mm) Dental Implants? A Systematic Review, Meta-Analysis, and Trial Sequential Analysis: Naples Consensus Report Working Group A," *Implant Dentistry* 28 (2019): 590–602.
5. T. Testori, F. Mandelli, M. Mantovani, S. Taschieri, R. L. Weinstein, and M. Del Fabbro, "Tilted Trans-Sinus Implants for the Treatment of Maxillary Atrophy: Case Series of 35 Consecutive Patients," *Journal of Oral and Maxillofacial Surgery* 71 (2013): 1187–1194.
6. R. Z. Araujo, J. F. Santiago Júnior, C. L. Cardoso, A. F. Benites Condezo, R. Moreira Júnior, and M. M. Curi, "Clinical Outcomes of Pterygoid Implants: Systematic Review and Meta-Analysis," *Journal of Cranio-Maxillo-Facial Surgery* 47 (2019): 651–660.
7. C. Stacchi, T. Lombardi, R. Ottonelli, F. Berton, G. Perinetti, and T. Traini, "New Bone Formation After Transcrestal Sinus Floor Elevation Was Influenced by Sinus Cavity Dimensions: A Prospective Histologic and Histomorphometric Study," *Clinical Oral Implants Research* 29 (2018): 465–479.
8. F. Khoury and T. Hanser, "Three-Dimensional Vertical Alveolar Ridge Augmentation in the Posterior Maxilla: A 10-Year Clinical Study," *International Journal of Oral & Maxillofacial Implants* 34 (2019): 471–480.
9. V. Moraschini, T. R. de Queiroz, S. C. Sartoretto, D. C. F. de Almeida, M. D. Calasans-Maia, and R. S. Louro, "Survival and Complications of Zygomatic Implants Compared to Conventional Implants Reported in Longitudinal Studies With a Follow-Up Period of at Least 5 Years: A Systematic Review and Meta-Analysis," *Clinical Implant Dentistry and Related Research* 25 (2023): 177–189.
10. C. Stacchi, S. Spinato, T. Lombardi, et al., "Minimally Invasive Management of Implant-Supported Rehabilitation in the Posterior Maxilla, Part II. Surgical Techniques and Decision Tree," *International Journal of Periodontics & Restorative Dentistry* 40 (2020): e95–e102.
11. B. M. Vetromilla, T. Mazzetti, and T. Pereira-Cenci, "Short Versus Standard Implants Associated With Sinus Floor Elevation: An Umbrella Review of Meta-Analyses of Multiple Outcomes," *Journal of Prosthetic Dentistry* 126 (2021): 503–511.
12. A. Ravidà, I. C. Wang, S. Barootchi, et al., "Meta-Analysis of Randomized Clinical Trials Comparing Clinical and Patient-Reported Outcomes Between Extra-Short (≤ 6 mm) and Longer (≥ 10 mm) Implants," *Journal of Clinical Periodontology* 46 (2019): 118–142.
13. E. A. Al-Moraissi, N. H. Altairi, B. Abotaleb, G. Al-Iryani, E. Halboub, and M. S. Alakhali, "What Is the Most Effective Rehabilitation Method for Posterior Maxillas With 4 to 8 mm of Residual Alveolar Bone Height Below the Maxillary Sinus With Implant-Supported Prostheses? A Frequentist Network Meta-Analysis," *Journal of Oral and Maxillofacial Surgery* 77, no. 70 (2019): e1–70.e33.
14. A. Ravidà, M. Galli, M. Bianchi, et al., "Clinical Outcomes of Short Implants (≤ 6 mm) Placed Between Two Adjacent Teeth/Implants or in the Most Distal Position: A Systematic Review and Meta-Analysis," *International Journal of Oral Implantology* 14 (2021): 241–257.
15. T. Albrektsson, G. Zarb, P. Worthington, and A. R. Eriksson, "The Long-Term Efficacy of Currently Used Dental Implants: A Review and Proposed Criteria of Success," *International Journal of Oral & Maxillofacial Implants* 1 (1986): 11–25.
16. S. Windael, B. Collaert, S. De Buyser, H. De Bruyn, and S. Vervaeke, "Early Peri-Implant Bone Loss as a Predictor for Peri-Implantitis: A 10-Year Prospective Cohort Study," *Clinical Implant Dentistry and Related Research* 23 (2021): 298–308.
17. P. Galindo-Moreno, A. Leon-Cano, I. Ortega-Oller, A. Monje, F. O'Valle, and A. Catena, "Marginal Bone Loss as Success Criterion in Implant Dentistry: Beyond 2 mm," *Clinical Oral Implants Research* 26 (2015): e28–e34.
18. P. Galindo-Moreno, A. Catena, M. Pérez-Sayáns, J. E. Fernández-Barbero, F. O'Valle, and M. Padial-Molina, "Early Marginal Bone Loss Around Dental Implants to Define Success in Implant Dentistry: A Retrospective Study," *Clinical Implant Dentistry and Related Research* 24 (2022): 630–642.
19. S. S. Pikner and K. Gröndahl, "Radiographic Analyses of "Advanced" Marginal Bone Loss Around Brånemark® Dental Implants," *Clinical Implant Dentistry and Related Research* 11 (2009): 120–133.
20. T. Jemt, S. Sundén Pikner, and K. Gröndahl, "Changes of Marginal Bone Level in Patients With "Progressive Bone Loss" at Brånemark System® Implants: A Radiographic Follow-Up Study Over an Average of 9 Years," *Clinical Implant Dentistry and Related Research* 17 (2015): 619–628.
21. T. Jemt and P. Coli, "Could Future Implant Failures Be Predicted Based on Observed Bone Levels and Bone Loss After 5 Years? A Retrospective Investigation on Patients Presented in Previous Studies," *International Journal of Oral & Maxillofacial Implants* 38 (2023): 259–267.
22. M. Cicciù, U. Pratella, L. Fiorillo, et al., "Influence of Buccal and Palatal Bone Thickness on Post-Surgical Marginal Bone Changes Around Implants Placed in Posterior Maxilla: A Multi-Centre Prospective Study," *BMC Oral Health* 23 (2023): 309.
23. T. Albrektsson, B. Chrcanovic, P. O. Östman, and L. Sennerby, "Initial and Long-Term Crestal Bone Responses to Modern Dental Implants," *Periodontology* 2000 2017, no. 73 (2000): 41–50.
24. W. Liu, J. Misch, and H. L. Wang, "The Influence of Supracrestal Tissue Adhesion on Implant Marginal Bone Level," *International Journal of Oral Implantology* 16 (2023): 3–6.
25. S. Spinato, C. Stacchi, T. Lombardi, et al., "Influence of Abutment Height and Vertical Mucosal Thickness on Early Marginal Bone Loss Around Implants. A Randomized Clinical Trial With an 18-Month Post-Loading Clinical and Radiographic Evaluation," *International Journal of Oral Implantology* 13 (2020): 279–290.
26. M. Tallarico, M. Caneva, S. M. Meloni, E. Khanari, U. Covani, and L. Canullo, "Definitive Abutments Placed at Implant Insertion and Never Removed: Is It an Effective Approach? A Systematic Review and

- Meta-Analysis of Randomized Controlled Trials," *Journal of Oral and Maxillofacial Surgery* 76 (2018): 316–324.
27. E. P. Pellizzer, J. M. de Luna Gomes, C. A. Araújo Lemos, L. Minatel, J. P. J. de Oliveira Limírio, and S. L. Dantas de Moraes, "The Influence of Crown-To-Implant Ratio in Single Crowns on Clinical Outcomes: A Systematic Review and Meta-Analysis," *Journal of Prosthetic Dentistry* 126 (2021): 497–502.
28. S. Soulami, D. E. Slot, and F. van der Weijden, "Implant-Abutment Emergence Angle and Profile in Relation to Peri-Implantitis: A Systematic Review," *Clinical and Experimental Dental Research* 8 (2022): 795–806.
29. V. K. Jansen, G. Conrads, and E. J. Richter, "Microbial Leakage and Marginal Fit of the Implant-Abutment Interface," *International Journal of Oral & Maxillofacial Implants* 2 (1997): 527–540.
30. A. Piattelli, G. Vrespa, G. Petrone, G. Iezzi, S. Annibaldi, and A. Scarano, "Role of the Microgap Between Implant and Abutment: A Retrospective Histologic Evaluation in Monkeys," *Journal of Periodontology* 74 (2003): 346–352.
31. I. Ericsson, L. G. Persson, T. Berglundh, C. P. Marinello, J. Lindhe, and B. Klinge, "Different Types of Inflammatory Reactions in Peri-Implant Soft Tissue," *Journal of Clinical Periodontology* 22 (1995): 255–261.
32. Y. Liu and J. Wang, "Influences of Microgap and Micromotion of Implant-Abutment Interface on Marginal Bone Loss Around Implant Neck," *Archives of Oral Biology* 83 (2017): 153–160.
33. M. A. Atieh, H. M. Ibrahim, and A. H. Atieh, "Platform Switching for Marginal Bone Preservation Around Dental Implants: A Systematic Review and Meta-Analysis," *Journal of Periodontology* 81 (2010): 1350–1366.
34. M. H. Kang, U. W. Jung, K. S. Cho, and J. S. Lee, "Retrospective Radiographic Observational Study of 1692 Straumann Tissue-Level Dental Implants Over 10 Years. II. Marginal Bone Stability," *Clinical Implant Dentistry and Related Research* 20 (2018): 875–881.
35. D. Hwang and H. L. Wang, "Medical Contraindications to Implant Therapy. Part I: Absolute Contraindications," *Implant Dentistry* 15 (2006): 353–360.
36. S. Spinato, F. Bernardello, T. Lombardi, et al., "Influence of Apico-Coronal Positioning of Tissue-Level Implants on Marginal Bone Stability During Supracrestal Tissue Height Establishment: A Multi-Center Prospective Study," *Clinical Implant Dentistry and Related Research* 24 (2022): 611–620.
37. R. Sentineri, T. Lombardi, F. Berton, and C. Stacchi, "Laurel-Gottlow Suture Modified by Sentineri for Tight Closure of a Wound With a Single Line of Sutures," *British Journal of Oral & Maxillofacial Surgery* 54 (2016): e18–e19.
38. G. Gomez-Roman and S. Launer, "Peri-Implant Bone Changes in Immediate and Non-Immediate Root-Analog Stepped Implants—A Matched Comparative Prospective Study up to 10 Years," *International Journal of Implant Dentistry* 2 (2016): 15.
39. No authors listed, "The Glossary of Prosthodontic Terms: Ninth Edition," *Journal of Prosthetic Dentistry* 117 (2017): e1–e105.
40. T. Linkevicius, P. Apse, S. Grybauskas, and A. Puisys, "Reaction of Crestal Bone Around Implants Depending on Mucosal Tissue Thickness. A 1-Year Prospective Clinical Study," *Stomatologija* 11 (2009): 83–91.
41. T. Linkevicius, P. Apse, S. Grybauskas, and A. Puisys, "The Influence of Soft Tissue Thickness on Crestal Bone Changes Around Implants: A 1-Year Prospective Controlled Clinical Trial," *International Journal of Oral & Maxillofacial Implants* 24 (2009): 712–719.
42. A. Barone, F. Alfonsi, G. Derchi, et al., "The Effect of Insertion Torque on the Clinical Outcome of Single Implants: A Randomized Clinical Trial," *Clinical Implant Dentistry and Related Research* 18 (2016): 588–600.
43. D. Baldi, T. Lombardi, J. Colombo, et al., "Correlation Between Insertion Torque and Implant Stability Quotient in Tapered Implants With Knife-Edge Thread Design," *BioMed Research International* 2018 (2018): 7201093.
44. L. Sennerby and N. Meredith, "Implant Stability Measurements Using Resonance Frequency Analysis: Biological and Biomechanical Aspects and Clinical Implications," *Periodontology* 2000 2008, no. 47 (2000): 51–66.
45. X. Yan, X. Zhang, W. Chi, H. Ai, and L. Wu, "Association Between Implant Apex and Sinus Floor in Posterior Maxilla Dental Implantation: A Three-Dimensional Finite Element Analysis," *Experimental and Therapeutic Medicine* 9 (2015): 868–876.
46. P. Galindo-Moreno, A. León-Cano, I. Ortega-Oller, et al., "Prosthetic Abutment Height Is a Key Factor in Peri-Implant Marginal Bone Loss," *Journal of Dental Research* 93 (2014): 80S–85S.
47. M. Katafuchi, B. F. Weinstein, B. G. Leroux, Y. W. Chen, and D. M. Daubert, "Restoration Contour Is a Risk Indicator for Peri-Implantitis: A Cross-Sectional Radiographic Analysis," *Journal of Clinical Periodontology* 45, no. 2 (2018): 225–232.
48. L. Lago, L. da Silva, I. Martinez-Silva, and B. Rilo, "Crestal Bone Level Around Tissue-Level Implants Restored With Platform Matching and Bone-Level Implants Restored With Platform Switching: A 5-Year Randomized Controlled Trial," *International Journal of Oral & Maxillofacial Implants* 33 (2018): 448–456.
49. F. L. Guljé, G. M. Raghoobar, B. Gareb, A. Vissink, and H. J. A. Meijer, "Single Crowns in the Posterior Maxilla Supported by Either 11-mm Long Implants With Sinus Floor Augmentation or by 6-mm Long Implants: A 10-Year Randomized Controlled Trial," *Clinical Oral Implants Research* 35 (2024): 89–100.
50. D. S. Thoma, R. Haas, K. Sporniak-Tutak, et al., "Randomized Controlled Multi-Centre Study Comparing Shorter Dental Implants (6 mm) to Longer Dental Implants (11–15 mm) in Combination With Sinus Floor Elevation Procedures: 10-Year Data," *Journal of Clinical Periodontology* 51 (2024): 499–509.
51. R. A. Jaffin and C. L. Berman, "The Excessive Loss of Branemark Fixtures in Type IV Bone: A 5-Year Analysis," *Journal of Periodontology* 62 (1991): 2–4.
52. D. Weng, Z. Jacobson, D. Tarnow, et al., "A Prospective Multicenter Clinical Trial of 3i Machined-Surface Implants: Results After 6 Years of Follow-Up," *International Journal of Oral & Maxillofacial Implants* 18 (2003): 417–423.
53. S. Feldman, N. Boitel, D. Weng, S. S. Kohles, and R. M. Stach, "Five-Year Survival Distributions of Short-Length (10 mm or Less) Machined-Surfaced and Osseointegrated Implants," *Clinical Implant Dentistry and Related Research* 6 (2004): 16–23.
54. Z. R. Esfahrood, L. Ahmadi, E. Karami, and S. Asghari, "Short Dental Implants in the Posterior Maxilla: A Review of the Literature," *Journal of the Korean Association of Oral and Maxillofacial Surgeons* 43 (2017): 70–76.
55. H. Abuhussein, G. Pagni, A. Rebaudi, and H. L. Wang, "The Effect of Thread Pattern Upon Implant Osseointegration," *Clinical Oral Implants Research* 21 (2010): 129–136.
56. P. Maló, N. M. de Araújo, A. Lopes, and S. Moss, "Posterior Maxillary Implants Inserted With Bicortical Anchorage and Placed in Immediate Function for Partial or Complete Edentulous Rehabilitations. A Retrospective Clinical Study With a Median Follow-Up of 7 Years," *Oral and Maxillofacial Surgery* 19 (2015): 19–27.
57. H. Moriwaki, S. Yamaguchi, T. Nakano, Y. Yamanishi, S. Imazato, and H. Yatani, "Influence of Implant Length and Diameter, Bicortical Anchorage, and Sinus Augmentation on Bone Stress Distribution: Three-Dimensional Finite Element Analysis," *International Journal of Oral & Maxillofacial Implants* 31 (2016): e84–e91.
58. P. Ng, X. Hu, S. Wan, H. Mo, and F. Deng, "Clinical Outcomes of Bicortical Engagement Implants in Atrophic Posterior Maxillae: A

- Retrospective Study With 1 to 5 Years Follow-Up," *International Journal of Periodontics & Restorative Dentistry* 38 (2018): e96–e104.
59. T. Testori, T. Clauser, A. M. Saibene, et al., "Radiographic Protrusion of Dental Implants in the Maxillary Sinus and Nasal Fossae: A Multidisciplinary Consensus Utilising the Modified Delphi Method," *International Journal of Oral Implantology* 15 (2022): 265–275.
60. S. Windael, B. Collaert, S. De Buyser, S. Vervaeke, and H. De Bruyn, "A 10-Year Retrospective Clinical Study to Identify Risk Indicators for Peri-Implant Bone Loss and Implant Failure," *Clinical Oral Implants Research* (2024), <https://doi.org/10.1111/clr.14375>.Online.
61. B. R. Chrcanovic, J. Kisch, T. Albrektsson, and A. Wennerberg, "A Retrospective Study on Clinical and Radiological Outcomes of Oral Implants in Patients Followed Up for a Minimum of 20 Years," *Clinical Implant Dentistry and Related Research* 20 (2018): 199–207.
62. P. Coli and T. Jemt, "On Marginal Bone Level Changes Around Dental Implants," *Clinical Implant Dentistry and Related Research* 23 (2021): 159–169.
63. S. Vandeweghe, D. Ferreira, L. Vermeersch, M. Mariën, and H. De Bruyn, "Long-Term Retrospective Follow-Up of Turned and Moderately Rough Implants in the Edentulous Jaw," *Clinical Oral Implants Research* 27 (2016): 421–426.
64. M. Raes, R. D'hondt, W. Teughels, W. Coucke, and M. Quirynen, "A 5-Year Randomized Clinical Trial Comparing Minimally With Moderately Rough Implants in Patients With Severe Periodontitis," *Journal of Clinical Periodontology* 45 (2018): 711–720.
65. C. Garaicoa-Pazmino, G. H. Lin, A. Alkandery, C. Parra-Carrasquer, and F. Suárez-López Del Amo, "Influence of Implant Surface Characteristics on the Initiation, Progression and Treatment Outcomes of Peri-Implantitis: A Systematic Review and Meta-Analysis Based on Animal Model Studies," *International Journal of Oral Implantology* 14 (2021): 367–382.
66. M. Quirynen and D. van Steenberghe, "Bacterial Colonization of the Internal Part of Two-Stage Implants. An In Vivo Study," *Clinical Oral Implants Research* 4 (1993): 158–161.
67. D. P. Callan, C. M. Cobb, and K. B. Williams, "DNA Probe Identification of Bacteria Colonizing Internal-Surfaces of the Implant-Abutment Interface: A Preliminary Study," *Journal of Periodontology* 76 (2005): 115–120.
68. J. S. Hermann, D. Buser, R. K. Schenk, and D. L. Cochran, "Crestal Bone Changes Around Titanium Implants. A Histometric Evaluation of Unloaded Non-submerged and Submerged Implants in the Canine Mandible," *Journal of Periodontology* 71 (2000): 1412–1424.
69. T. Berglundh and J. Lindhe, "Dimension of the Periimplant Mucosa. Biological Width Revisited," *Journal of Clinical Periodontology* 23 (1996): 971–973.
70. D. L. Cochran, J. S. Hermann, R. K. Schenk, F. L. Higginbottom, and D. Buser, "Biologic Width Around Titanium Implants. A Histometric Analysis of the Implanto-Gingival Junction Around Unloaded and Loaded Nonsubmerged Implants in the Canine Mandible," *Journal of Periodontology* 68 (1997): 186–198.
71. C. Tomasi, F. Tessarolo, I. Caola, J. Wennström, G. Nollo, and T. Berglundh, "Morphogenesis of Peri-Implant Mucosa Revisited: An Experimental Study in Humans," *Clinical Oral Implants Research* 25 (2014): 997–1003.
72. S. Vervaeke, M. Dierens, J. Besseler, and H. De Bruyn, "The Influence of Initial Soft Tissue Thickness on Peri-Implant Bone Remodeling," *Clinical Implant Dentistry and Related Research* 16 (2014): 238–247.
73. T. Linkevicius, A. Puisys, M. Steigmann, E. Vindasiute, and L. Linkeviciene, "Influence of Vertical Soft Tissue Thickness on Crestal Bone Changes Around Implants With Platform Switching: A Comparative Clinical Study," *Clinical Implant Dentistry and Related Research* 17 (2015): 1228–1236.
74. T. Lombardi, F. Berton, S. Salgarello, et al., "Factors Influencing Early Marginal Bone Loss Around Dental Implants Positioned Subcrestally: A Multicenter Prospective Clinical Study," *Journal of Clinical Medicine* 8 (2019): 1168.
75. R. Judgar, G. Giro, E. Zenobio, et al., "Biological Width Around One- and Two-Piece Implants Retrieved From Human Jaws," *BioMed Research International* 2014 (2014): 850120.
76. J. Blanco, A. Pico, L. Caneiro, L. Nóvoa, P. Batalla, and P. Martín-Lancharro, "Effect of Abutment Height on Interproximal Implant Bone Level in the Early Healing: A Randomized Clinical Trial," *Clinical Oral Implants Research* 29 (2018): 108–117.
77. S. Spinato, C. Stacchi, T. Lombardi, F. Bernardello, M. Messina, and D. Zaffe, "Biological Width Establishment Around Dental Implants Is Influenced by Abutment Height Irrespective of Vertical Mucosal Thickness: A Cluster Randomized Controlled Trial," *Clinical Oral Implants Research* 30 (2019): 649–659.
78. M. Muñoz, E. Busoms, J. Vilarrasa, M. Albertini, V. Ruiz-Magaz, and J. Nart, "Bone-Level Changes Around Implants With 1- Or 3-mm-High Abutments and Their Relation to Crestal Mucosal Thickness: A 1-Year Randomized Clinical Trial," *Journal of Clinical Periodontology* 48 (2021): 1302–1311.
79. Z. Chen, C. Y. Lin, J. Li, H. L. Wang, and H. Yu, "Influence of Abutment Height on Peri-Implant Marginal Bone Loss: A Systematic Review and Meta-Analysis," *Journal of Prosthetic Dentistry* 122 (2019): 14–21.e2.
80. P. Tajti, E. Solyom, S. Váncsa, et al., "Less Marginal Bone Loss Around Bone-Level Implants Restored With Long Abutments: A Systematic Review and Meta-Analysis," *Periodontology* 2000 2024, no. 94 (2000): 627–638.
81. M. A. Atieh, M. Shah, M. Ameen, A. Tawse-Smith, and N. H. M. Alsabeeha, "Influence of Implant Restorative Emergence Angle and Contour on Peri-Implant Marginal Bone Loss: A Systematic Review and Meta-Analysis," *Clinical Implant Dentistry and Related Research* 25 (2023): 840–852.
82. C. Gatti, F. Gatti, M. Silvestri, et al., "A Prospective Multicenter Study on Radiographic Crestal Bone Changes Around Dental Implants Placed at Crestal or Subcrestal Level: One-Year Findings," *International Journal of Oral & Maxillofacial Implants* 33 (2018): 913–918.
83. C. Stacchi, L. Lamazza, A. Rapani, et al., "Marginal Bone Changes Around Platform-Switched Conical Connection Implants Placed 1 or 2mm Subcrestally: A Multicenter Crossover Randomized Controlled Trial," *Clinical Implant Dentistry and Related Research* 25 (2023): 398–408.
84. R. S. Cruz, C. A. A. Lemos, J. M. de Luna Gomes, H. F. Fernandes E Oliveira, E. P. Pellizzer, and F. R. Verri, "Clinical Comparison Between Crestal and Subcrestal Dental Implants: A Systematic Review and Meta-Analysis," *Journal of Prosthetic Dentistry* 127 (2022): 408–417.