KEY WORDS
Short implant, Standard implant, Fixed single crown, Dental implant, Randomized clinical trial

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A THREE-YEAR TWO-CENTER RANDOMIZED CONTROLLED TRIAL COMPARING SINGLE 6-MM VERSUS 10-MM LONG IMPLANT-SUPPORTED CROWNS IN POSTERIOR JAWS

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PURPOSE. The aim of this study was to compare the clinical and radiographic outcomes of single dental implants of two different lengths (6 mm versus 10 mm) placed in healed posterior sites and restored with single crowns.

MATERIALS AND METHODS. Forty patients requiring a single implant-supported restoration in the posterior regions of the maxilla or mandible were selected and randomized to receive either 6-mm implants (test group, n = 20) or 10-mm implants (control group, n = 20). Impressions were taken three months after placement, and the implants were restored with single fixed crowns. The primary outcome was implant failure. Secondary outcomes included changes in peri-implant marginal bone levels, biological and mechanical complications, and gingival health indicators such as plaque index (PI), calculus index (CI), bleeding index (BI), and probing depth (PD).

RESULTS. Forty implants, all featuring a double acid-etched and sandblasted surface, were placed successfully, with no drop-outs. One 6-mm implant failed during the 1st year. Three years after loading, no drop-out occurred with no difference in success rates between the test and control group (-5% with a 95% confidence interval, CI 95% -15 to +5%; p-value = 1).
One patient in the 6-mm group and six patients of the 10-mm group were affected by complications, the difference was not statistically significant (-25% with a 95% CI ranging from -52.5% to +2.5%; p-value = 0.0915).
No statistically significant differences were observed at the final follow-up for gingival health indicators between the test and control groups: 21% versus 15% for positive plaque index, with a difference of +6% (CI 95%: -23.2 to +35.2%; p-value = 0.6947); 36.9% versus 50% for a positive bleeding index, with a difference of -13.1% (CI 95%: -49.1 to +22.9%; p-value = 0.8517); and 2.6mm versus 2.7mm for probing depth with a difference of -0.10mm (CI 95%: -0.43 to +0.23mm; p-value = 0.7680).
Both groups exhibited a decrease in marginal bone levels from baseline to the 3-year follow-up (-1.08+0.40mm and -1.02+0.40mm, respectively for short and standard groups), with an observed test-standard difference in means of -0.06±0.40mm (CI 95%: -0.22 to +0.10; p-value = 0.1849).

CONCLUSIONS. This study found no statistically significant differences in outcomes between 6-mm and 10-mm implants supporting single crowns in the posterior maxilla or mandible. Both implant lengths demonstrated high success rates and comparable clinical and radiographic performance over the 3-year follow-up period.

CONFLICT OF INTEREST STATEMENT

The corresponding author, on behalf of all contributors, certifies that present research is free of conflict of interest; moreover, all the authors and the authors' institutions have not financial or personal relationships with other people or organizations those inappropriately influence their actions, except for Tommaso Grandi, who serves as a consultant for JDental Care (Modena, Italy).

This study was completely self-financed and no funding was sought or obtained, not even in the form of free material.

Doi: 10.36130/CTD.06.2024.03

INTRODUCTION

The loss of vertical bone height poses a significant challenge when placing dental implants in the posterior regions of the maxilla and/or mandible. Bone augmentation procedures, such as guided bone regeneration, bone block grafting, or sinus augmentation, are often necessary to facilitate the placement of conventional dental implants in such cases[1]. However, these augmentation procedures often reduce patient compliance due to various factors, including high costs, extended treatment durations, risk of graft infection, invasive techniques, and the need for a large amount of autogenous bone as graft material. Consequently, alternative treatments are needed.

Short dental implants (6 mm in length) have been developed as a viable option for placement in areas with insufficient vertical bone volume[2]. Early studies on short implants reported less favorable clinical outcomes compared to conventional or longer implants (at least 10 mm in length)[3,4]. However, subsequent research attributed the higher failure rate of short dental implants primarily to implant surface properties rather than implant length itself. Indeed, short dental implants with rough surfaces have demonstrated clinical outcomes comparable to those of longer implants, as confirmed by recent randomized clinical trials[5-8].

Nevertheless, comparisons between 6-mm short implants and standard-length implants (10 mm or longer) have shown no significant differences in clinical and radiographic outcomes. Short implants might therefore offer an alternative for implant placement in patients with limited ridge height, although they have been associated with a reduced first-year survival rate[9-11]. A meta-regression analysis suggested that, particularly in the maxilla, each additional 1 mm in implant length increased the survival rate by 0.68 percentage points, highlighting the potential impact of implant length on long-term survival rates[12].

Short dental implants were now considered a viable alternative to bone augmentation procedures in the posterior regions of the maxilla and/or mandible[13,14]. However, direct comparisons between short and longer implants placed without augmentation procedures remained relatively limited. Furthermore, only a few meta-analyses provided long-term data comparing short and standard implants with similar surface designs[15,16]. Single tooth replacement presented one of the most challenging scenarios, as these implants were subjected to greater loads and bite forces compared to those supporting multi-unit restorations.

The aim of this randomized controlled trial was to compare the clinical outcomes of single 6-mm dental implants with 10-mm implants placed in posterior jaws. The null hypothesis was that there would be no differences in outcomes between the two treatment strategies, with the alternative hypothesis suggesting a potential difference. This study was conducted and reported in accordance with the CONSORT statement for improving the quality of RCT reporting (http://www.consort.stetement.org/) and presented results up to three years after loading.

MATERIALS AND METHODS

This was a double-center, parallel-group, randomized controlled trial conducted in two Italian Modena (Dr Tommaso Grandi) and Padua (Dr Filippo Casotto) between April 2021 and June 2024. The study adhered to the principles outlined in the Declaration of Helsinki on clinical research involving human subjects and followed Good Clinical Practice guidelines. All patients received comprehensive information about the study and provided written informed consent prior to participation. The study was approved by the Ethics Committee of Saint Camillus International University of Health and Medical Sciences (Protocol Number: E00664-2021).

Patient selection

To be eligible for the study, participants had to meet the following inclusion criteria:

- age between 18 and 80 years and the ability to provide informed consent;
- absence of a single tooth in the posterior regions of the maxilla and/or mandible;
- sufficient residual bone height to allow the placement of at least a 10-mm-long dental implant;
- presence of teeth/prosthesis in the opposing arch to ensure occlusal contacts with the implant-supported crown.

Exclusion criteria were:

- inability to attend follow-up appointments at the treating center;
- general contraindications for implant surgery;
- history of irradiation in the head or neck region;
- immunodeficiency or immunocompromised conditions;
- current or previous treatment with intravenous amino-bisphosphonates;
- poor oral hygiene or lack of motivation;
- untreated periodontitis, occlusal parafunctions, uncontrolled diabetes, substance abuse, psychiatric conditions, or unrealistic expectations.

Subjects were consecutively recruited and randomly assigned to receive either a 6-mm or a 10-mm implant. All surgical and prosthetic procedures were performed by two operators (FC and TG).

Randomization

Sequence Generation

The randomization sequence was generated using a computer-based random number generator, ensuring equal allocation of dental sites to the two study groups and centers. To achieve an equal distribution of participants in the test and control groups at each center, a block randomization sequence was employed.

Allocation Concealment

To ensure allocation concealment, the sequence was placed into opaque, sealed envelopes. These envelopes were numbered sequentially and stored securely until the moment of the surgical procedure. The preparation and sealing of the envelopes were conducted by a staff member not involved in clinical assessments or implant placements to maintain the blinding of the allocation process. At the time of surgery, the clinical investigators opened the next envelope in the sequence to determine the implant type assignment. The process was repeated for each patient to maintain randomization and ensure unbiased allocation. The surgical team performing the implant placement adhered strictly to the allocation revealed by the envelopes. Two single randomization sequences were generated using block randomization with a random block size.

Pre-implant assessment of patient health

A comprehensive medical history was obtained for all participants. Preoperative radiographic evaluations - including periapical, panoramic, or cone beam CT scans - along with detailed clinical inspections, were performed to assess bone volume and ensure appropriate treatment planning.
All patients underwent at least one session of professional hygiene and debridement prior to surgery. Antimicrobial prophylaxis (1 g of amoxicillin plus clavulanic acid or clarithromycin 500 mg for patients allergic to penicillin) was administered before surgery and continued twice daily for one week.

Procedure

On the day of surgery, local anesthesia was administered using articaine with adrenaline (1:100,000). After raising a full-thickness flap, the implant length was determined by opening a sequentially numbered sealed envelope corresponding to the patient's recruitment number. Tapered titanium screw-shaped dental implants with an internal connection and a sand-blasted, acid-etched surface (JDEvolution Plus system, JDentalCare, Modena, Italy) were placed following the manufacturer's protocol.

Healing abutments were attached, and the implants underwent non-submerged healing. Interrupted sutures were placed and removed after 10 days. After a three-month healing period, all implants were restored with metal-ceramic screw-retained crowns, adhering to the standard prosthetic protocol. Following prosthesis delivery, patients received professional dental hygiene maintenance every six months. Occlusion was assessed at each visit to ensure stability and proper function.

FIGS. 1, 2 display intraoral X-rays of two patients from the study, representing the 6-mm and 10-mm groups (a total of four subjects).

Post-clinical assessments

Patients attended weekly recall appointments during the first month post-surgery, followed by monthly visits until implant loading. Subsequently, follow-up visits were scheduled at 3, 6, 12, 24, and 36 months. Additional postoperative radiographic evaluations were performed during clinical assessments as needed. At the final follow-up, a comprehensive clinical examination was conducted.

Outcomes measures

The primary outcome was implant failure, assessed using the following criteria[17]:

· implant mobility or the need for the removal of a stable implant due to progressive marginal bone loss, infection, or mechanical complications rendering the implant unusable (e.g., implant fracture or deformation of the connecting platform). Implant stability was evaluated manually by tightening the abutment screw with a torque wrench set at 30 Ncm; any spinning implant was recorded as a failure.

An implant was considered a success if it presented:

- no evidence of peri-implant radiolucency;
- marginal bone loss not exceeding 1.5 mm during the first year, followed by an average annual bone loss of no more than 0.2 mm;
- absence of pain, discomfort, or infection.

Otherwise, the implant was classified as a surviving implant.

The secondary outcomes included:

- All biological and mechanical complications occurring throughout the follow-up period were recorded and analyzed by the study group.

Biological complications:

- peri-implant infections, classified as peri-implant mucositis (heavily inflamed soft tissue without bone loss) and peri-implantitis (gingival pockets ≥5 mm, bleeding on probing, presence of radiographically detectable bone loss, and concurrent clinical attachment loss).
- clinical evidence of an abscess and/or fistula;
- prolonged anesthesia or paresthesia (temporary or permanent);
- abnormal or prolonged pain following implant insertion.

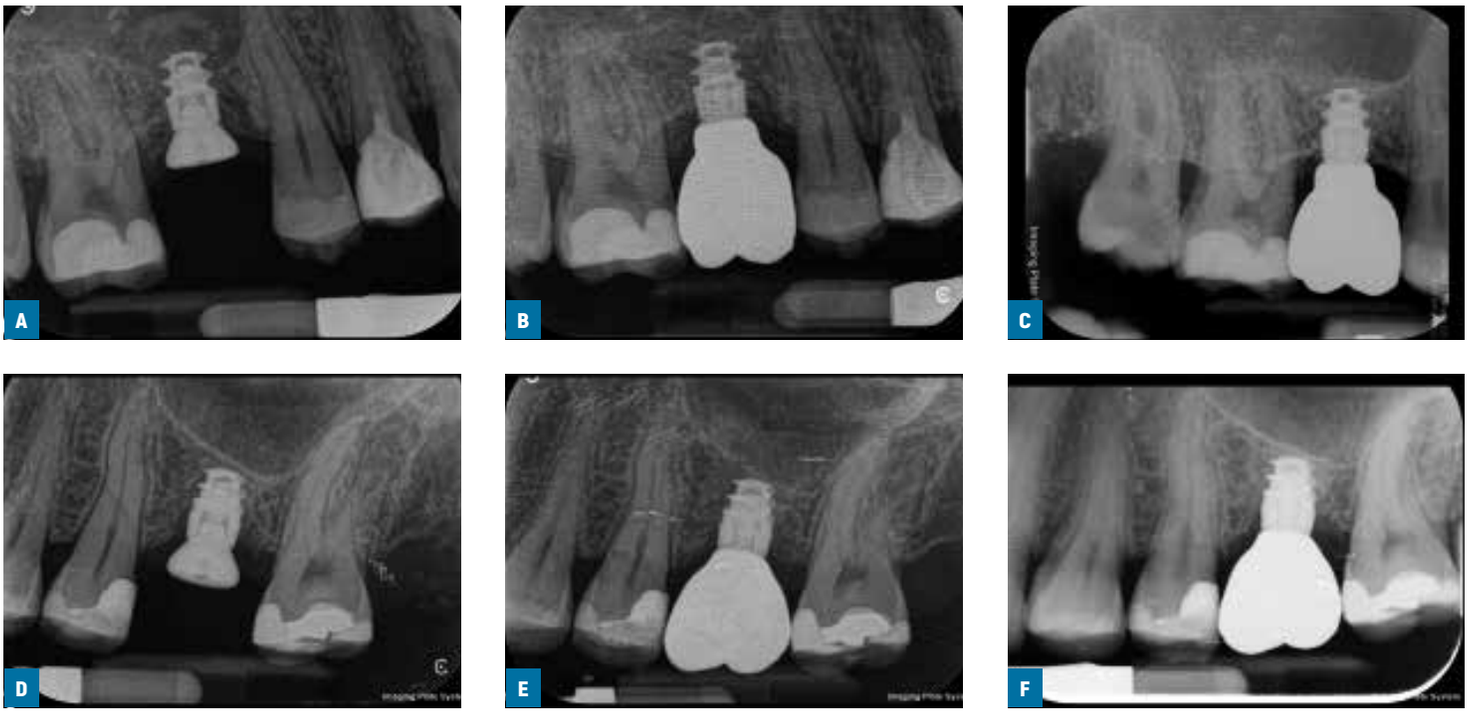

FIG. 1: *intra-oral x-rays of two patients included in the 6-mm group. A and D) baseline; B and E) 12 months; C and F) 36 months intraoral radiographs*

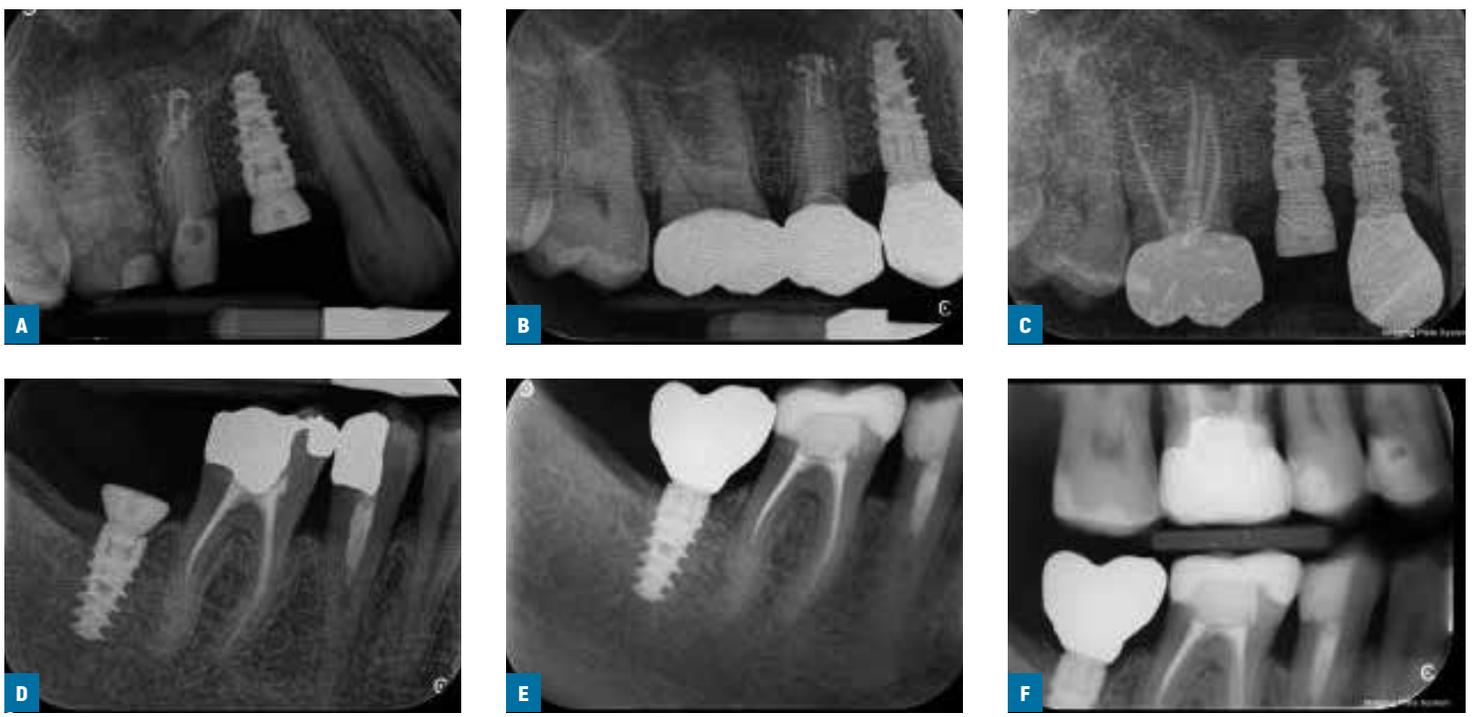

FIG. 2: *intra-oral x-rays of two patients included in the 10-mm group. A and D) baseline; band E) 12 months; C and F) 36 months intraoral radiographs*

Mechanical complications included fractures or loosening of prosthetic components, evaluated clinically and radiographically.

- Clinical evaluations were performed during follow-up visits by the operators who were obviously not blinded to group allocation.
  - Plaque accumulation: measured using a modified Plaque Index (PI) with the following scores: score 0, no detection of plaque; score 1, plaque only recognized by running a probe across the smooth marginal surface of the implant; score 2, plaque visible to the naked eye; score 3, abundant soft matter[18,19].
  - Bleeding on probing: assessed when a periodontal probe was passed along the gingival margin adjacent to the implant using the modified sulcus Bleeding Index (BI) with scores: score 0, no bleeding; score 1, isolated bleeding spots; score 2, blood forms a confluent red line on margin; score 3, heavy or profuse bleeding[18,19].
  - Calculus Index (CI): evaluated dichotomously as absence of calculus (score 0) or presence of calculus (score 1)[19].
  - Pocket Probing Depth (PD): measured at four sites per implant (mesial, buccal, distal, and lingual) using a manual periodontal probe (Colorvue, Hu-Friedy)[18,19]. The distance between the marginal border of the mucosa and the tip of the periodontal probe was scored as the probing depth. The highest value per implant was used for analysis.
  - Peri-implant Marginal Bone Loss: peri-implant marginal bone levels were assessed using intraoral radiographs taken with the paralleling technique at baseline (immediately after implant placement), and at 12 and 36 months post-loading. An independent assessor (TP) performed all measurements. Radiographs were digitized in JPG format, then converted to TIFF format at a resolution of 600 dpi and stored on a personal computer. Peri-implant marginal bone levels were analyzed using Image J 1.42 software (National Institute of Mental Health, Maryland, USA). The software was calibrated for each image based on the known implant diameter. For each implant, mesial and distal crestal bone levels adjacent to each implant were rounded to the nearest tenth of a millimeter and averaged at the patient level. The measurements were taken parallel to the implant axis. Reference points for the linear measurements were the most coronal margin of the implant collar and the most coronal point of bone-to-implant contact. Marginal bone loss was calculated using the following equation:

A single clinician (Dr Paolo Toti) assessed bone levels at periapical radiographs, in an unblinded way since the implant length was clearly visible on the radiographs.

Sample size

The non-inferiority power calculation described by Blackwelder was used to determine the study group[21,22]. The sample size was calculated based on a per-protocol analysis, estimating that 16 patients per group (total n = 32) would be needed to achieve approximately 80% power to demonstrate the non-inferiority of 6-mm implants compared to 10-mm implants. This calculation assumes an implant failure rate of 3% in both the experimental and control groups and a non-inferiority margin of 15%. To account for a 15% dropout rate, a minimum of 20 participants per group was recruited.

Statistical analysis

All analyses followed a pre-established plan, with patients as the unit of evaluation. A dentist with interests in statistics (Dr Paolo Toti) conducted all analyses using the Statistics Toolbox, (MatLab 7.11). The null hypothesis (H0): no differences existed between the outcomes of the 6-mm and 10-mm implant groups. Homoscedasticity was tested using the Brown-Forsythe test but was not confirmed. Normality was tested using the Shapiro-Wilk analysis but was not confirmed.

Variables were described as means ± standard deviation. Differences for continuous outcomes were analyzed using the Wilcoxon rank-sum test for unmatched samples, while within-group comparisons were performed using the Wilcoxon signed-rank test for paired data. Differences in proportions between groups and subgroups were analyzed using the Fisher's exact test and the chi-square test. Prevalence data were presented in contingency tables as needed. All analyses were conducted at a 0.05 significance level.

RESULTS

Forty-five subjects were screened for eligibility, but five subjects were not enrolled for the following reasons: three patients were hesitant to undergo implant treatment, one was a substance abuser, and one had been treated with intravenous amino-bisphosphonates.
A total of 40 subjects (20 implants per center) were included in the study. Patient characteristics and clinical parameters are detailed in **TABLE 1**. Six patients in the 6-mm group and

TABLE 1 FEATURES OF THE SUBJECTS (N = 40) INCLUDED IN THE STUDY

	Test: 6 mm short implants n = 20			Control: 10 mm standard implants n = 20		
age (in years)	54.4(16.8)			55.5(15.7)		
variable	**rank**	**count (failure)**	**percent**	**rank**	**count (failure)**	**percent**
gender	female male	13(1) 7	65% 35%	female male	15 5	75% 25%
implant position	bicuspid molar	5 15(1)	25% 75%	bicuspid molar	3 17	15% 85%
bone quality (I, II, III, IV)	type I type II type III type IV	1 8 9 2(1)	5% 40% 45% 10%	type I type II type III type IV	2 14 4 0	10% 60% 20% 0%
smokers	no £ 10 cigarettes/day > 10 cigarettes/day	14 5(1) 1	70% 25% 5%	no £ 10 cigarettes/day > 10 cigarettes/day	13 6 1	65% 30% 5%
concomitant diseases	no hypertension diabetes bruxism thyroid disease	14(1) 2 1 3 0	70% 10% 5% 15% 0%	no hypertension diabetes bruxism thyroid disease	11 5 2 3 1	55% 25% 10% 15% 5%
opposite dentition	natural dentition crown on implant crown on tooth	15(1) 3 2	75% 15% 10%	natural dentition crown on implant crown on tooth	13 4 3	65% 20% 15%
insertion torque (Ncm)	15 25 30 35 40 45 50 60 80	1 1 5(1) 2 0 2 0 4 5	5% 5% 25% 10% 0% 10% 0% 20% 25%	15 25 30 35 40 45 50 60 80	0 0 3 0 1 2 1 5 8	0% 0% 15% 0% 5% 10% 5% 25% 40%

seven in the 10-mm group were smokers. Bone quality types were similarly distributed across the two groups, with type II and type III being the most common. A total of 40 dental implants were placed in the premolar and molar regions, with 20 implants measuring 6 mm in length (test group) and 20 implants measuring 10 mm (control group). The study flowchart and implant distribution between groups are illustrated in **FIG. 3**. No patients were lost to follow-up, and all surviving implants completed the 3-year evaluation period, with patients attending the final follow-up visit.

Implant success

One test mandibular implant failed 10 months postoperatively, after prosthetic loading. The subject, a moderate smoker (less than 10 cigarettes/day), was a healthy female with bone quality classified as type IV. The implant was inserted with a torque of approximately 30 Ncm and exhibited a moderate bleeding index (score = 1) at the first follow-up visit (1 month). The single failure reported in the short implant group resulted in a difference in success rates between the test and control groups of -5% (CI95%: -15 to +5%; p-value = 1).

Complications

Peri-implant mucositis was observed in one patient in the 6-mm group and three patients of the 10-mm group. Abutment screw loosening was exclusively observed in three patients of

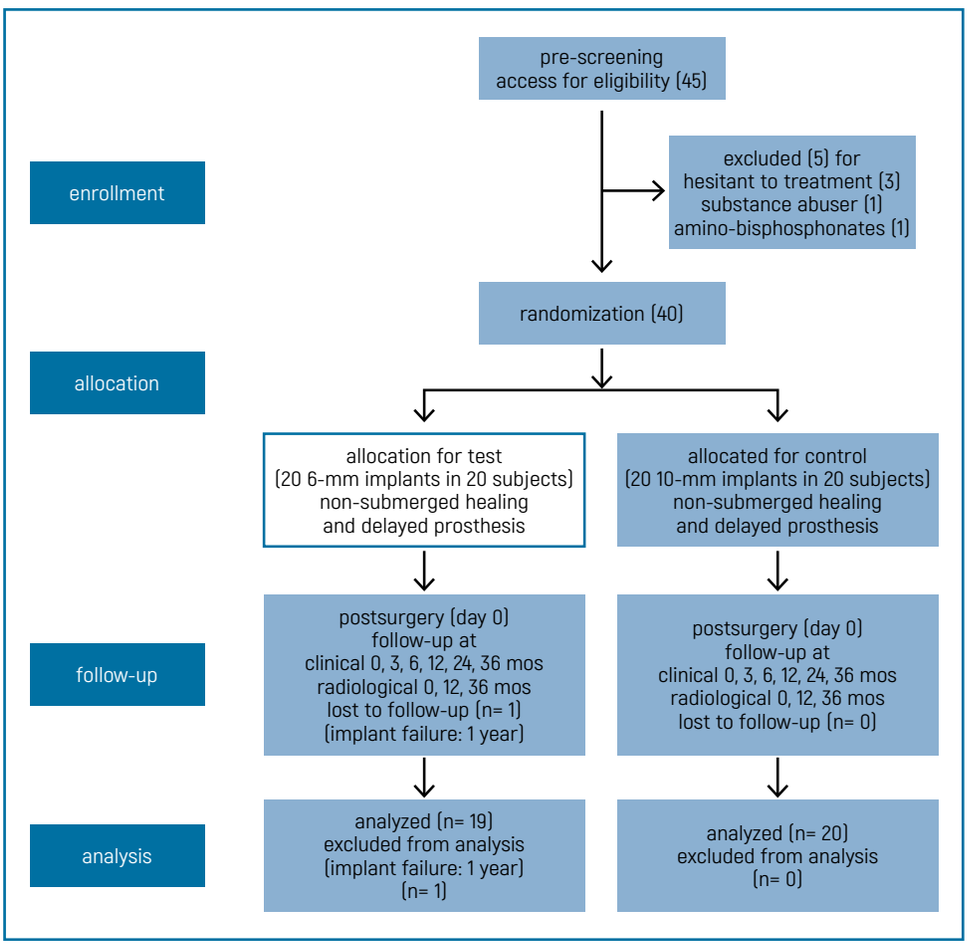

FIG. 3: *flow-chart of the study. Patients allocated into one of the two groups (test using 6-mm short implants or 10-mm standard implants) was done using a computer-generated randomization list*

the 10-mm group. One patient in the 6-mm group and six patients of the 10-mm group were affected by complications, the difference was not statistically significant (-25% with a 95% CI ranging from -52.5% to +2.5%; p-value = 0.0915).

Indices for peri-implant health

All indices and scores are described in detail in **TABLE 2**.

TABLE 2 FREQUENCIES AND PERCENTAGES (IMPLANT-BASED) OF PLAQUE-INDEX SCORES (POSSIBLE SCORE 0-3), CALCULUS-INDEX SCORES (POSSIBLE SCORE 0-1), BLEEDING-INDEX SCORES (POSSIBLE SCORE 0-3) AND MEDIAN VALUE, INTERQUARTILE RANGE, AND MINIMUM-MAXIMUM VALUE OF PROBING DEPTH (IN MM) AT 1 MONTH (T1), 1 YEAR (T12), AND 3 YEARS (T36) AFTER PLACEMENT OF THE CROWN

	implant groups (size)		T1				T2				T3			
		score	0	1	2	3	0	1	2	3	0	1	2	3
plaque index	test: 6-mm short implants	count	20	0	0	0	18	1	0	0	15	4	0	0
		percent	100	0	0	0	94.7	5.3	0	0	79	21	0	0
	control: 10-mm standard implants	count	20	0	0	0	19	1	0	0	17	3	0	0
		percent	100	0	0	0	95	5	0	0	85	15	0	0
test vs. control		p-value	1*				1*				0.6947*			
difference in percentage			0%				+0.3% ± 14.2%				+6% ± 29.2%			
95% confidence interval			N.D.				[-13.9% +14.5%]				[-23.2% +35.2%]			
calculus index	test: 6-mm short implants	count	20	0			19	0			19	0		
		percent	100	0			100	0			100	0		
	control: 10-mm standard implants	count	20	0			20	0			20	0		
		percent	100	0			100	0			100	0		
test vs. control		p-value	1*				1*				1*			
difference in percentage			0%				0%				0%			
95% confidence interval			N.D.				N.D.				N.D.			
bleeding index	test: 6-mm short implants	count	18	2	0	0	13	5	1	0	12	6	1	0
		percent	90	10	0	0	68.4	26.3	5.3	0	63.1	31.6	5.3	0
	control: 10-mm standard implants	count	19	1	0	0	11	5	4	0	10	7	3	0
		percent	95	5	0	0	55	25	20	0	50	35	15	0
test vs. control		p-value	1*				0.6488°				0.8517°			
difference in percentage			+5% ± 21.5%				-13.4% ± 35.3%				-13.1% ± 36.0%			
95% confidence interval			[-16.5% +26.5%]				[-48.7% +22.0%]				[-49.1 +22.9]			
probing depth (mm)	test: 6-mm short implants	median(iqr)	2.4(0.6)				2.5(0.6)				2.6(0.7)			
		min - max	1-4				2-4				2-5			
	control: 10-mm standard implants	median(iqr)	2.2(0.7)				2.6(0.8)				2.7(0.7)			
		min - max	1-4				2-5				2-5			
test vs. control		p-value	0.4407#				0.3466#				0.7680#			
difference in percentage			+0.20±0.29				-0.10±0.33				-0.10±0.33			
95% confidence interval			[-0.09 +0.49]				[-0.43 +0.23]				[-0.43 +0.23]			

*Wilcoxon ranksum test #; Fisher exact test *, Chi-square test with Yates' correction °, N.D. non-detectable.*

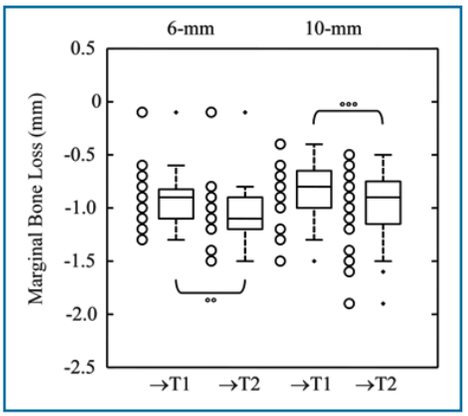

FIG. 4: *scatter (full-points) and box plots for the marginal bone loss at different time points: from baseline to 1 year (➔1yr) and from baseline to 3 years (➔3yrs) for the two groups, 6-mm and 10-mm implants. in the box-and-whiskers plot, the box line represents the lower, median, and upper quartile values; the whisker lines include the rest of the data. Outliers (solid x) were data with values beyond the ends of the whiskers. wilcoxon signed rank test: ° significant (p-value < 0.01), °° very significant (p-value < 0.001), °°° extremely significant (p-value < 0.0001)*

Plaque index: at baseline, 100% of subjects in both groups exhibited a score of 0. At 1 year, a score of 1 was observed in 5.3% and 5% of participants in the 6-mm and 10-mm groups, respectively. By 3 years, the proportion of participants with a score of 0 decreased to 79% in the 6-mm group and 85% in the 10-mm group. The difference in percentages between the groups was negligible at 1 year (+0.3%) and slightly higher at 3 years (+6%) in favor of the short implant group.

Differences in bleeding index scores were observed between groups over time. At 1 year, 68.4% of the 6-mm group had a score of 0, compared to 55% in the 10-mm group. Scores 1 and 2 were observed in 26.3% and 5.3% of the 6-mm group and in 25% and 20% of the 10-mm group, respectively. By 3 years, the score of 0 decreased to 63.1% in the 6-mm group and 50% in the 10-mm group. Differences between groups were pronounced at the 1-year (-13.4%) and 3-year (-13.1%) follow-ups in favor of the short implant group.

At all intervals, 100% of participants in both groups exhibited a calculus score of 0, with no differences detected between groups.

Probing depth (PD) increased slightly in both groups over time. In the 6-mm group, PD increased from 2.4 mm to 2.6 mm, while in the 10-mm group it rose from 2.2 mm to 2.7 mm. Differences in PD between groups were minimal and within the range of variability, with a slight negative difference (-0.10 mm) at 1 and 3 years in favor of the short implant group.

Peri-implant marginal bone loss

Marginal bone levels and bone loss were analyzed at implant placement, and at 12 and 36 months post-loading, as detailed in **TABLE 3** and **FIG. 4**. Similar trends were observed from

TABLE 3 MARGINAL BONE LEVEL AT IMPLANT PLACEMENT (BASELINE OR T0), THEN AT 12- (T1), AND 36-MONTH SURVEY (T2). MARGINAL BONE LOSS AS CHANGES IN MBLS BETWEEN TIMES (ΔDMBL = MBL_{POSTOP} – $MBL_{BASELINE}$) OR BASELINE➔T1 AND BASELINE➔T2. THE TWO GROUPS SHOWED SHAPIRO-WILK SIGNIFICANCE AND VARIANCE FOR EACH GROUP: TEST (6-MM SHORT IMPLANTS) VERSUS CONTROL (10-MM STANDARD IMPLANTS). HOMOSCEDASTICITY ASSUMPTION AND RESULTS OF BROWN-FORSYTHE'S TEST FOR THE VARIABLES: MARGINAL BONE LEVEL, F = 4.2231, DF1 = 5, DF2 = 111, P-VALUE = 0.0015; MARGINAL BONE LOSS, F = 0.3480, DF1 = 3, DF2 = 74, P-VALUE = 0.7907

groups		times	implant placement (baseline)	12 months after loading (T1)	36 months after loading (T2)	marginal bone loss (baseline → T1)	marginal bone loss (baseline → T2)	p-value between marginal bone loss
test (n=19)	MBL (mm)	mean+std	+0.02+0.07	-0.96+0.27	-1.04+0.39	-0.96+0.28	-1.08+0.40	**0.0002**
	Shapiro-Wilk test	p-value	**0.0004**	**0.0151**	**0.0103**	**0.0278**	**0.0169**	
	Brown-Forsythe's test	variance	0.0036	0.0732	0.0936	0.0820	0.1004	
control (n=20)	MBL (mm)	mean(std)	+0.01+0.07	-0.83+0.30	-1.03+0.39	-0.85+0.28	-1.02+0.40	**<0.0001**
	Shapiro-Wilk test	p-value	**0.0015**	0.2627	0.1146	0.2055	0.0845	
	Brown-Forsythe's test	Variance	0.0058	0.0899	0.1346	0.0950	0.1382	
test vs. control		p-value	0.3679	0.1824	0.2516	0.1455	0.1849	
test - control	MBL (mm)	difference in means	+0.01±0.07	-0.13±0.29	-0.01±0.39	-0.11±0.28	-0.06±0.40	
test - control	MBL (mm)	95% confidence interval	[-0.03 +0.05]	[-0.21 +0.05]	[-0.17 +0.15]	[-0.23 +0.01]	[-0.22 +0.10]	

baseline to the follow-up periods of 12 and 36 months. At the 3-year follow-up, the 6-mm group demonstrated a marginal bone loss of -1.08±0.40 mm, compared to -1.02±0.40 mm in the 10-mm group. The difference in means was -0.06±0.40 mm in favor of the standard implant, with a 95% CI of -0.22 to +0.10 mm (p = 0.1849).

DISCUSSION

The results of this randomized controlled trial revealed no statistically significant differences between short implants (6 mm) and longer implants (10 mm) for single-tooth replacement in the posterior jaw regions. Minimal crestal bone loss was observed during the 3-year follow up period, with no statistically significant differences between the two groups.

In all complication categories, the test group consistently demonstrated a lower complication rate than the control group. However, the wide confidence intervals and p-values above 0.05 indicated substantial variability and limited statistical significance, warranting cautious interpretation. While both groups exhibited marginal bone loss over time, the differences in bone levels and bone loss were neither statistically nor clinically significant. These findings suggested comparable performance between 6-mm and 10-mm implants over the 36-month observation period. These outcomes aligned with recent studies investigating the performance of short implants with similarly rough surfaces[5-8].

The current findings corroborated the conclusions of a recent systematic review and meta-analysis by Lee and colleagues, which included four randomized clinical trials evaluating short implants with rough surfaces.[23] That analysis found no linear relationship between implant length and success rate. While earlier studies suggested that longer implants might achieve higher success rates, particularly over the long term, the present results were consistent with findings from short-term follow-ups (up to 36 months). However, ongoing surveillance might be necessary to determine if differences emerged over the long-term, as indicated by another randomized clinical trial reporting significantly different survival rates: 86.7% for 6-mm implants versus 96.7% for 10-mm implants after 5 years[3]. That study attributed short implant failures primarily to probable fractures of the surrounding bone.

The use of short implants for single-tooth replacement remained challenging due to significant loading forces in these cases. The reduced implant-to-bone contact area in short implants compared to standard-length implants could be a critical factor for patients with high bite forces. In this study, only one 6-mm implant failed, occurring in the posterior mandible 10 months after loading. No failures of short implants were observed before loading. While this might appear inconsistent with previous reports (e.g., a systematic review showing that 71% of short implant failures occurred before loading[24], the limited sample size in the present study likely accounted for this discrepancy.

Plaque, calculus, gingival, and bleeding scores remained very low at the 3-year evaluation. Both the 6-mm and 10-mm implant groups demonstrated comparable outcomes, with minor differences in plaque and bleeding indices slightly favoring the control group at the 3-year follow-up. Probing depth increased marginally in both groups, with no significant differences. The strict oral hygiene protocols followed by participants likely contributed to maintaining healthy peri-implant tissues. These favorable outcomes were further supported by the low mean probing depth (2.5-2.7 mm), consistent with previous studies[3,25]. Despite these encouraging results[6-8], evidence supporting the unrestricted use of short implants, especially for long-term applications, remained limited.

Certain risk factors - such as a history of periodontal disease, diabetes, or smoking - could increase the likelihood of peri-implantitis and implant failure. In this study, 10% of subjects had diabetes, and 30% were active smokers, underscoring the importance of carefully considering short implants for these populations.

The short-term data supported the use of short implants as a viable option in cases of severe bone atrophy, especially for patients who declined bone augmentation procedures - such as guided bone regeneration, bone block grafting, or sinus augmentation - due to financial, psychological, or systemic health concerns.

This study had several limitations. The small sample size and the lack of blinding were the primary limitations. The focus on posterior regions limited the generalizability of the findings to anterior regions, where bone densities and loading conditions differed. Posterior regions were chosen for their higher biomechanical demands, which might affect implant performance differently than in anterior areas. Lastly, the experimental nature of this study, wherein short implants were placed in sites where standard implants would traditionally be used, might not fully account for systemic factors influencing bone loss and short implant survival in cases of low bone volume. While the study design provided valuable insights, these limitations should be considered when interpreting the results and applying them to broader clinical practice.

CONCLUSIONS

Despite the small sample size, this study suggested similar failure rates, complications, gingival health, and marginal bone loss for short (6 mm) and standard-length (10 mm) implants supporting single crowns in the posterior maxilla and/or mandible over 36 months of functional loading. These findings supported the use of short implants as a viable treatment option.

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