Primary and Secondary Stability of Short (4 mm) Versus Standard (≥ 10 mm) Implants Placed in the Same Mandible: A Prospective Clinical Study

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Purpose: To compare the stability of short vs standard (ie, regular-length) implants in the edentulous mandible. ***Materials and Methods:*** In this prospective clinical study, 20 patients with edentulous mandibles received four implants each—two short implants (4 mm) in the region of the first molar and two standard implants (≥ 10 mm) in the interforaminal region. Implant stability was assessed using resonance frequency analysis immediately after implant placement and at the day of the abutment connection after 3 months of healing in order to provide an implant stability quotient (ISQ). ***Results:*** Implant stability in the two implant groups at placement (ISQ: short 66.2; standard 68.2) and at abutment connection (ISQ: short 74.9; standard 75.7) did not differ substantially or statistically significantly (both $P > .05$). Findings did not change after statistically controlling for potential confounders such as bone quality and bone crest width. At abutment connection, 95% of the short and 97.5% of the standard implants demonstrated sufficient stability for conventional loading ($P > .05$). ***Conclusions:*** Short dental implants demonstrate similar primary and secondary stability compared to standard implants and seem to be a promising treatment option for rehabilitation of patients with edentulous mandibles. *Int J Oral Maxillofac Implants 2023;38:733–738. doi: 10.11607/jomi.10096*

Keywords: dental implants, short implants, implant stability, resonance frequency analysis

Implant placement in the posterior mandible can present a complex case for the clinician when there is extensive bone loss in that region.[1] To avoid damage to anatomical structures in close proximity (eg, the mandibular nerve[2,3]) and to achieve a prosthetically optimal implant position,[4,5] treatment alternatives such as extensive bone augmentation, vertical distraction osteogenesis, and short implants have been introduced.[6–8] The use of short implants (< 6 mm) placed without the need for tissue regeneration techniques can be a promising approach for such cases. Short implants seem to have several advantages, including lower treatment cost, reduced surgical time, and decreased patient discomfort, as well as less complexity from the clinician's point of view.[8–10]

The rationale for the use of short implants is the stability gained from the cortical bone, which in most cases constitutes the first few millimeters of the alveolar bone.[11,12] Stability is an important and crucial factor for a successful outcome in dental implant prosthetics. Implant failure is associated with a continuous decrease of stability over time.[13,14] Implant stability can be specified as a combination of primary and secondary stability. *Primary stability* refers to the mechanical engagement of an implant with the surrounding bone. In contrast, *secondary stability* is related to bone regeneration and remodeling processes taking place in the implant-bone interface and thus refers to biologic stability.[15,16] Moreover, primary implant stability seems to be correlated with secondary stability, because a well-stabilized implant can lead to a greater degree of osseointegration and thus a more secure restoration. However, high primary stability can negatively affect the bone level stability.[16,17]

A variety of methods have been suggested to evaluate primary and/or secondary implant stability in clinical practice. Among them, the insertion torque test, Periotest (Siemens AG), and resonance frequency analysis can be applied in daily routine, and there is a strong correlation between these methods regarding the evaluation of implant stability.[18–20] Resonance frequency analysis measurement provides information about the implant-bone interface as a specific parameter called the *implant stability quotient* (ISQ). ISQ values of 60 or higher refer to successfully osseointegrated implants,

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while an ISQ lower than 50 may indicate potential failure or high risk of failure.[14,21–23] Implants of different lengths have already demonstrated similar stability measurements.[24,25] However, there is a limited number of studies that focus on the stability measurement of implants with a length of 4 mm.[26]

The purpose of this study was intraindividual comparison of the primary and secondary stability of short vs standard implants in the edentulous mandible.

MATERIALS AND METHODS

Design and Setting

This study is part of a split-mouth, nonrandomized clinical trial conducted in the Department of Prosthetic Dentistry at the University Medical Center Hamburg-Eppendorf (Hamburg, Germany). It was carried out in accordance with the Declaration of Helsinki and was approved by the Institutional Review Board of the Medical Association in Hamburg on November 25th, 2014 (PV 4805). All patients signed written informed consent. This study was documented according to the CONSORT guidelines and registered at ClinicalTrials.gov (identifier: NCT04838184).[27]

Participants

A total of 20 patients, each with a completely edentulous mandible in need of treatment, were consecutively recruited for this study. Sample size calculation was based on the main study outcomes: clinical survival and success rate of short implants after 5 years. Because failure of either of the two short implants would result in failure of the restoration and therefore exclusion of the second implant, a conservative approach in sample size calculation was applied to estimate an overall survival rate on patient level. Based on current evidence for survival of short implants,[28,29] a sample size of 18 subjects was deemed sufficient to measure a 90% survival rate with a lower limit of the 95% confidence interval (CI) of 65% after 5 years. Based on an expected lost to follow-up rate of 10%, the number of subjects to be included in the study was 20.

Patients were excluded from the study if they demonstrated any of the following: compromised general health that would not allow surgical treatment or a restorative procedure, need for major bone augmentation procedures, heavy smoking (> 10 cigarettes/day), or alcohol or drug abuse. Further exclusion criteria included ongoing infections in adjacent tissue of the planned implantation site or opposing teeth or implants, uncontrolled diabetes, or allergic reactions to the restorative material. Finally, pregnant or lactating women and patients with severe bruxism or other destructive oral habits were also excluded.

During the inclusion and healing phase, all patients wore a complete denture in the mandible. In the maxilla, 15 (75%) had a complete denture, 3 (15%) had a telescopic denture, and 2 (10%) had an implant bar–supported denture.

Clinical Procedure

Each implant was placed following a two-stage approach with backward planning. First, a radiographic template was fabricated according to the ideal dental arch position and utilized in a CBCT (Orthophos XG 3D, Dentsply Sirona). Bone quality of the implant site was assessed according to the Lekholm and Zarb classification.[30] Using implant planning software (CoDiagnostiX, Dental Wings), the height and width of the alveolar bone crest were measured, and ideal size, axis, and position of the implants were visualized. Because submerged healing was planned, the implants were placed at bone level. The chosen implant diameter was either 4.1 or 4.8 mm according to the available bone at each implant site, to achieve at least 1.5 mm of bone thickness lingually and buccally. The radiographic template was reworked into a surgical template following coordinates delivered from the planning software.

Patients received 2 g amoxicillin orally 1 hour prior to implant placement. Local anesthesia was performed with 4% articaine and 1:100,000 epinephrine (Ultracain D-S forte, Sanofi). After preparation of a mucoperiosteal flap, guided surgery was performed using the surgical template. Implant placement was carried out according to the manufacturer's protocol. In cases where minor bone grafting was necessary (ie, small dehiscence or exposed threads), bone substitute material (Geistlich Bio-Oss, Geistlich Pharma) covered with a collagen membrane (Geistlich Bio-Gide, Geistlich Pharma) was utilized. Before suture application, cover screws were installed.

Each patient received four implants (Straumann Roxolid/SLActive Standard Plus, Straumann AG): two standard implants with a minimum length of 10 mm in the interforaminal region and two short (4-mm) implants in the region of the first molar.

After suturing for closed healing, the removable provisional denture was polished and cleared, ensuring that no pressure was applied on the implants, with the use of a denture soft relining silicone when needed (Ufi Gel SC, VOCO). Patients received oral hygiene instructions in addition to a daily mouthwash for 10 days (Chlorexamed Forte alcohol-free 0.2%, GlaxoSmithKline) and postoperative medication (eg, ibuprofen 600 mg), and they were advised to maintain a soft diet for 2 weeks. The nonresorbable sutures were removed 10 days postoperatively.

After 3 months of closed healing without loading, a split-thickness flap was raised to facilitate healing abutment connection. In cases where there was < 3 mm of attached gingiva, a free gingival graft (FGG) was carried out.[31]

Table 1 Clinical Data for All Implants

Clinical measures	All	Implant length		Significance
		Short (4 mm)	Standard (≥ 10 mm)	
		N (%) or mean (SD) [range]		*P* value
Implant diameter				< .001
4.1 mm	61 (76.3)	21 (52.5)	40 (100.0)	
4.8 mm	19 (23.8)	19 (47.5)	0 (0.0)	
Bone quality				.053
Type I	15 (18.8)	9 (22.5)	6 (15.0)	
Type II	32 (40.0)	16 (40.0)	16 (40.0)	
Type III	24 (30.0)	13 (32.5)	11 (27.5)	
Type IV	9 (11.3)	2 (5.0)	7 (17.5)	
Crest width (mm)	6.5 (1.5) [4.0–12.2]	6.7 (1.6) [4.0–12.2]	6.3 (1.3) [4.1–8.7]	.286
Screw torque (Ncm)	31.9 (4.8) [15.0–35.0]	31.4 (5.4) [15.0–35.0]	32.5 (4.1) [20.0–35.0]	.296
Bone grafting				.101
No	62 (77.5)	35 (87.5)	27 (67.5)	
Yes	18 (22.5)	5 (12.5)	13 (32.5)	
FGG				.179
No	43 (53.8)	20 (50.0)	23 (57.5)	
Yes	37 (46.3)	20 (50.0)	17 (42.5)	

*Percentages may not total 100 due to rounding.

Stability Measurements

Implant stability was measured with the Osstell II device (Osstell). Measurements were conducted in mesiodistal and buccolingual directions. ISQ values of all implants were measured at implant placement and at the time of healing abutment connection.

Statistical Analysis

Descriptive statistics included the presentation of proportions or means and SD of patient characteristics and clinical parameters of each implant site at baseline. Differences within patients between clinical parameters for implant location (anterior versus posterior) were tested using mixed-effect linear or ordered logistic regression, respectively, with the patient as a random effect to account for intercorrelations within each patient.

The impact of implant length on implant stability represented by ISQ values was analyzed for implant placement (primary stability) and at abutment connection (secondary stability) using univariate analyses followed by multivariate analyses statistically controlled for potential confounders (implant side, bone quality, crest width, bone grafting). Mixed-effect linear regression models were applied. As a sensitivity analysis, this model was computed separately for standard and short implants to reveal whether clinical parameters and procedures differently affect implant stability.

Additionally, the clinically acceptable ISQ values for conventional loading (at least 60) were examined and analyzed with respect to implant length using mixed-effect ordered logistic regression models.

All statistical tests were two-sided with an alpha level of .05. All statistical tests were performed using STATA/MP (Stata Statistical Software: Release 14).

RESULTS

Patient Characteristics and Clinical Measures

In total, 20 participants (9 female and 11 male) with an age range of 48 to 74 years (mean: 62.6 years) received 80 implants in total. The majority of short and standard implants (40%) were placed in alveolar bone with quality type II (Table 1). The screw torque at placement ranged from 15.0 to 35.0 Ncm with a mean (SD) of 31.9 (4.8) and no statistically significant differences with respect to implant length ($P = .296$). No implants were lost during the study period.

Impact of Implant Length on Implant Stability

At implant placement, implant stability did not differ substantially or statistically significantly between short implants (ISQ: mean 66.2) and standard implants (ISQ: mean 68.2; $P = .124$; Table 2). Implant length revealed no

Table 2 Measures of Implant Stability (ISQ) at Placement and Abutment Connection

Assessment	All	Implant length		Significance
		Short (4 mm)	Standard (≥ 10 mm)	
	Mean (SD) [range]			*P* value
Placement	67.2 (8.7) [37–80]	66.2 (9.3) [37.0–80.0]	68.2 (8.1) [44.5–78.5]	.124
Abutment connection	75.3 (5.5) [56–85]	74.9 (5.8) [56.0–85.0]	75.7 (5.2) [56.0–85.0]	.527

Table 3 Regression Models for Impact of Implant Length on Implant Stability (ISQ) at Implant Placement (Model 1), Statistically Controlled for Potential Confounders (Model 2)

	Coefficient	95% CI	*P* value
Model 1			
Implant length (standard [≥ 10 mm])	2.1	−0.6; 4.7	.124
Model 2			
Implant length (standard [≥ 10 mm])	3.3	−0.6; 7.3	.094
Implant side (left)	0.7	−2.2; 3.5	.634
Implant diameter (4.8 mm)	0.5	−5.2; 6.2	.859
Bone quality			
Type I	–	–	–
Type II	0.6	−5.2; 6.4	.835
Type III	0.1	−6.2; 6.3	.980
Type IV	−4.8	−13.2; 3.7	.262
Crest width	−0.1	−1.5; 1.3	.873
Bone grafting (yes)	−2.4	−6.7; 1.8	.252

Table 4 Regression Models for Impact of Implant Length on Implant Stability (ISQ) at Implant Abutment Connection (Model 3), Statistically Controlled for Potential Confounders (Model 4)

	Coefficient	95% CI	*P* value
Model 3			
Implant length (regular [≥ 10 mm])	0.8	−1.7, 3.3	.527
Model 4			
Implant length (regular [≥ 10 mm])	1.8	−2.1, 4.5	.481
Implant side (left)	0.8	−1.8, 3.3	.546
Implant diameter (4.8 mm)	−1.3	−5.4; 2.9	.552
Bone quality			
Type I			
Type II	1.5	−2.5, 5.5	.447
Type III	3.4	−0.8, 7.6	.108
Type IV	−3.2	−8.7, 2.2	.237
Crest width	−0.3	−1.4, 0.7	.537
Bone grafting (yes)	−2.7	−6.1, 0.8	.125

statistically significant impact on primary implant stability (Table 3, Model 1). Findings did not change substantially after statistically controlling for potential confounders (Table 3, Model 2). Even though the impact of clinical parameters and procedures differed somewhat when short and standard implants were considered separately, all coefficients were not statistically significant (all $P > .05$; Appendix Table1).

Implant stability was somewhat higher at abutment connection than at implant placement. Nevertheless, implant stability did not differ substantially or statistically significantly between short implants (ISQ: mean 74.9) and standard implants (ISQ: mean 75.7; $P = .527$; Table 2). An ISQ value of 60 or higher was observed for almost all short (95%) and standard (97.5%) implants with no statistically significant difference ($P = .563$). Implant length had no statistically significant impact on secondary stability, as indicated from the reported *P* value (Table 4, Model 3). Findings did not change substantially after statistically controlling for potential confounders (Table 4, Model 4). As observed for implant placement, the impact of clinical parameters and procedures differed somewhat when short and standard implants were considered separately, but again coefficients were not statistically significant (all $P > .05$; Appendix Table 2).

DISCUSSION

This is the first study providing evidence to support the equivalence of short 4-mm implants and standard implants with a length ≥ 10 mm in terms of primary and secondary implant stability.

When the observed ISQ values were interpreted, the differences were not statistically significant. Both implant groups exhibited similar mean ISQ values and ranges at the time of implant placement and at the time of abutment

connection. As expected, screw torque values at placement were also comparable for both implant groups, as a positive correlation between screw torque and ISQ has been confirmed.[18] Because factors relating to bone structure can have an effect on implant stability,[19,32] they were taken into account in the current analysis, but they did not yield a statistically or clinically significant difference.

These findings are well comparable to those of the literature. In a split-mouth study, Adánez et al[33] reported comparable clinical outcomes between short and standard implants in the posterior mandible after 1 year of loading. The mid-term prognosis of short implants in the posterior mandible has also been reported to be as good as that of standard implants after 5 years of loading.[34,35] Esposito et al[36] reported similar results between 5-mm implants and 10-mm implants placed in augmented bone in posterior edentulous jaws after 3 years of loading. There was also a preference for the posterior mandible for rehabilitation with short implants due to its better bone quality compared to the maxilla. In addition, the results of the present study support the findings of Rokn et al[26] that 4-mm implants can have similar outcomes to longer implants. In the retrospective study by Hentschel et al[37] evaluating 273 short implants and 303 standard implants with resonance frequency analysis after osseointegration, the data did not yield any statistically significant difference between ISQ values. A finite element analysis performed by Pierrisnard et al[38] revealed that maximum stress in the implant area was largely independent of implant length. Balleri et al[39] similarly documented ISQ levels from 57 to 82 with a mean of 69 after 1 year of loading for successfully osseointegrated implants, which is somewhat lower than that observed the present study.

The present study has strengths and limitations. A noninvasive method of measuring implant stability with high predictability was used to evaluate the impact of length on the primary and secondary stability of implants.[18,21,40] The examined implants had identical sandblasted/acid-etched surface modification (Straumann SLActive, Straumann) and shape (Straumann Standard Plus, Straumann), while they differed in length and thread count. The fact that each patient received two implants from each length is another strength because this can be considered as repeated measures increasing precision of estimates and simultaneously reducing variance due to intraindividual comparisons. The structure of bone was also taken into account in terms of quality and quantity as a factor that can determine the implant stability. As part of a long-term study, sample size calculation was based on the main study and, thus, a probable lack of statistical power cannot be excluded. For the same reason, randomization and blinding could not be performed. Because anterior and posterior sites received different implants, a certain bias can be expected. Furthermore, the posterior mandible provides good cortical bone quality, ensuring better primary stability values compared to other regions (eg, the edentulous maxilla).[32,36] The implants used were of a certain design and surface modification, and therefore the findings of the study may not apply for every short implant available. In addition, measurement of alveolar bone width indicates the surrounding bone volume at a certain point of the implant surface, but not the amount of bone across the implant surface. However, primary implant stability depends on cortical bone thickness, which is limited in the first 2 to 3 mm of the alveolar bone.[41]

The findings of the current study point to similarities in terms of the primary and secondary stability of implants from the same manufacturer. Further development under loaded conditions could provide valuable data regarding the survival of short implants. A therapeutic approach with short implants could be appreciated by patients and clinicians alike, as it is less invasive, simpler, and more time and cost effective compared to extensive two-stage bone augmentation procedures.[6,42–45]

CONCLUSIONS

Short (4-mm) implants placed in the posterior mandible achieve similar primary and secondary stability to standard implants and are therefore a promising treatment option for the edentulous mandible.

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APPENDIX

Appendix Table 1 Regression Models for Impact of Clinical Parameters and Procedures on Implant Stability (ISQ) at Implant Abutment Connection, Stratified for Implant Length

	Short implants			Standard implants		
	Coefficient	95% CI	*P* value	Coefficient	95% CI	*P* value
Bone quality						
Type I	–	–	–	–	–	–
Type II	2.7	–2.8, 8.2	.326	–1.8	–9.4, 5.7	.620
Type III	2.7	–3.2, 8.5	.350	2.3	–4.7, 9.3	.508
Type IV	–4.5	–14.4, 5.4	.346	–5.3	–13.9, 3.3	.217
Crest width	–1.0	–2.4, 0.4	.162	–0.5	–2.4, 1.4	.592
Bone grafting (yes)	–2.6	–8.7, 3.5	.399	–4.6	–10.7, 1.5	.138

Appendix Table 2 Regression Models for Impact of Clinical Parameters and Procedures on Implant Stability (ISQ) at Implant Placement, Stratified for Implant Length

	Short implants			Standard implants		
	Coefficient	95% CI	*P* value	Coefficient	95% CI	*P* value
Bone quality						
Type I	–	–	–	–	–	–
Type II	0.6	–8.2, 9.5	.884	–2.1	–11.0, 6.8	.634
Type III	–3.3	–13.6, 7.0	.516	–1.8	–10.8, 7.1	.674
Type IV	–12.6	–31.7, 6.5	.181	–8.9	–19.6, 1.9	.102
Crest width	–0.8	–2.9, 1.4	.467	–1.9	–4.7, 0.9	.186
Bone grafting (yes)	–1.3	–10.2, 7.5	.758	–4.2	–12.3, 3.9	.294