Outcomes of 6.5-mm Hydrophilic Implants and Long Implants Placed with Lateral Sinus Floor Elevation in the Atrophic Posterior Maxilla: A Prospective, Randomized Controlled Clinical Comparison

Huajie Yu, MD, DDS;* Xing Wang, MD, DDS;† Lixin Qiu, MD, DDS‡

ABSTRACT

Background: Very few controlled studies have compared short and long implants placed with appropriate sinus floor elevation techniques.

Purpose: To compare the 2-year outcomes of 6.5-mm hydrophilic implants placed with osteotome sinus floor elevation (OSFE) and standard implants placed with lateral sinus floor elevation in patients with a severely atrophic posterior maxilla.

Materials and Methods: Thirty-eight patients with a residual bone height of 4–5 mm were randomized to receive one of the two above-mentioned treatments. Intra- and postoperative complications were recorded. The implant survival rate, peri-implant bone level, and periapical endosinus bone gain were assessed.

Results: Of the 80 inserted implants, one in the long implant group failed because of abscess formation. The peri-implant bone level change (0.35 ± 0.60 mm vs 0.40 ± 0.71 mm) was not significantly different between the two groups. The endosinus bone gain was 2.94 ± 0.81 mm and 10.19 ± 0.95 mm in the short and long implant groups, respectively. No serious adverse events related to implant surgery were recorded.

Conclusions: The results suggest that the placement of 6.5-mm short implants with OSFE is an effective alternative for the rehabilitation of a severely atrophic posterior maxilla.

KEY WORDS: atrophic maxilla, bone formation, maxillary sinus floor elevation, randomized controlled trial

INTRODUCTION

Implant placement is a routine treatment for edentulous and partially edentulous patients. Rehabilitation of an atrophic posterior maxilla is challenging because of not only limited maxillary residual bone height (RBH) associated with ridge resorption and sinus pneumatization but also low bone density.[1] When the available bone height does not allow the placement of long dental implants, sinus elevation using the lateral window approach is the most commonly performed augmentation procedure.[2] A systematic review by Wallace & Froum showed that the mean survival rate of implants placed in conjunction with sinus floor elevation involving the lateral approach was 91.8% (range 61.7–100%).[3] The grafted sinus is generally left to heal for ≥6 months to facilitate new bone formation or else implants are inserted simultaneously during a one-stage procedure.[4] However, such techniques are expensive and technique sensitive. Moreover, the entire treatment duration is

*Prosthodontist, Restoration/Data analysis, 4th Dental Department, Peking University School and Hospital of Stomatology, Beijing, China; †Professor, Critical revision of article, President of Chinese Stomatological Association, Beijing, China; ‡Professor, Surgery/Approval of article, Dean of 4th Dental Department, Peking University School and Hospital of Stomatology, Beijing, China

Corresponding Author: Lixin Qiu, MD, DDS, 4th Dental Department, Peking University School and Hospital of Stomatology, Beijing 100081, China; e-mail: yuhuajie666@aliyun.com

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too long and increases the risk of postoperative complications.

At present, emphasis is placed on the simplification of surgical protocols to improve patient comfort during the operative and postoperative period. The use of short implants offers a simpler and cheaper alternative to invasive surgical techniques.[5] However, clinical follow-up of short implants has suggested decreased bone–implant contact and primary stability.[6] In a previous study, 6-mm short implants placed with osteotome sinus floor elevation (OSFE) were found to be associated with lower predictability and success rates.[7] However, others reported that patients with an RBH of <5 mm can be successfully treated with short implants.[8] Implant surface modifications, together with improved surgical techniques, compensate for the adverse effects of the decreased implant length.[9] In patients with a decreased RBH in the maxilla, OSFE can be applied with short implant placement. Sul and colleagues reported that bone gain after sinus elevation without grafting could not exceed 3.2 mm.[10] Nedir and colleagues showed that 6.4 mm of bone anchorage may be sufficient to ensure implant function in the maxillary posterior region.[11] Therefore, for the rehabilitation of atrophic posterior maxillae with an RBH of 4–5 mm, 6.5-mm implants can be placed in conjunction with OSFE without grafting. Spontaneous bone formation below the sinus membrane extending around the implants can be expected.

In most patients, the posterior maxilla has bone quality of type 3 or 4.[12] Reduced bone quality generally does not facilitate the primary stability of implants; therefore, the posterior maxilla is associated with important risk factors that may jeopardize the survival of short traditional implants.[13] A 44% failure rate of implants was reported in maxillary type 4 bone as a result of the trabecular bone content.[12] Pommer and colleagues, in a cadaver study, concluded that bone density seems to be the major determinant of primary stability in maxillary sinus augmentation with simultaneous implant placement, while RBH had no influence.[14] At the same time, cancellous bone exhibits faster remodeling and can be easily influenced by implant surface modifications.[15]

Compared with a sandblasted-acid etched implant surface, hydrophilic dental implant surfaces reportedly increase bone to implant contact and enhance removal torque values, especially during the early phase.[16] In vitro, hydrophilic surfaces are favorable for blood clot formation and osteogenic differentiation of mesenchymal stem cells.[17] To date, two different technologies have been used and are commercially available to prepare hydrophilic dental implants. The first involves rinsing of the surface under nitrogen protection, followed by storage in isotonic saline, while the second involves surface treatment with aqueous sodium hydroxide. Nedir and colleagues have reported successful results for the use of 8-mm short implants with hydrophilic surfaces in severely atrophic maxillae.[11] However, only two published randomized controlled trials (RCTs) have compared 6.5-mm short implants and longer implants placed with lateral sinus floor elevation in the atrophic posterior maxilla.[9,18] Both RCTs exhibited a high risk of bias from group imbalance, because the control group systematically received implants with a smaller diameter than that of implants received by the test group.

The primary aim of the present RCT was to compare the survival rates between 6.5-mm short implants and standard long implants placed with appropriate sinus floor elevation techniques in the atrophic posterior maxilla, while the secondary aim was to evaluate peri-implant bone resorption, endosinus bone gain, and surgical complications associated with two strategies. The null hypothesis was that there are no differences between the two implant types in terms of survival rates, clinical function, and prognosis over a 2-year follow-up duration.

MATERIALS AND METHODS

This study was designed as a prospective randomized clinical trial. Patients were recruited according to the inclusion and exclusion criteria detailed in Table 1. The sample size was calculated on the basis of a previous study[19] to detect a preference for short implants against the alternative hypothesis that both short and long implants were equally preferred. This provided a simple one-sample proportion scenario. A one-group chi-square test with a two-sided significance level of 0.050 would yield an 80% power to detect a difference between the null proportion of 0.500 and the alternative proportion of 0.900 when the sample size for each group was 10. This size was doubled, because we hypothesized that patient preference would not be

TABLE 1 Inclusion and Exclusion Criteria for Participation in the Study

Inclusion criteria
• Voluntary informed consent
• Age >18 years
• Adequate RBH of 4–5 mm under the maxillary sinus
• Buccolingual bone width of at least 6.5 mm
• Edentulous opposing dentition with a denture (implant-borne or conventional) or natural teeth
• Placement of 4.5-mm implants without concurrent bone augmentation
• A minimum healing period of 4 months after tooth extraction
Exclusion criteria
• General contraindications for implant surgery
• Severe hemophilia
• History of irradiation in the head and neck region less than 1 year before the study
• Poor oral hygiene
• Uncontrolled diabetes
• Pregnancy or lactating status
• Psychiatric problems or unrealistic expectations
• HIV infection
• Smoking of >10 cigarettes or cigar equivalents per day or chewing of tobacco corresponding to >10 cigarette equivalents per day
• Acute infection in the area intended for implant placement
• Local inflammation, including untreated periodontitis
• Severe bruxism or clenching habits
• Presence of osseous lesions

as well differentiated in this trial. In total, 42 partially edentulous patients with atrophic posterior maxillae were included.

The study protocol was evaluated and approved by the institutional ethics committee (PKUSSIRB-201310081) prior to patient selection. The registration number was ChiCTR-OCC-15006902.

Study Design

Patients were consecutively selected from those seeking implant rehabilitation between February 12, 2012 and January 31, 2013 at the 4th Dental Department, Peking University School and Hospital of Stomatology. Patients were randomized to receive either 11–12.5-mm standard implants (Thommen Medical AG, Grenchen, Switzerland) simultaneously with lateral sinus floor elevation (long implant group) or 6.5-mm hydrophilic implants (Inicell®, Thommen Medical AG, Grenchen, Switzerland) simultaneously with OSFE (short implant group; Figure 1). Randomization was performed using sealed envelopes that were opened after bone exposure during surgery. In the long implant group, the final restorations were fixed at the 16-week follow-up visit, while in the short implant group, the implants were loaded with provisional restorations at 8 weeks after implant placement and final restorations at 16 weeks. If both sinuses met the enrollment requirements, the right side was treated by the procedure assigned through randomization and the left side was treated by the other procedure.

Clinical Procedures

Preoperative Procedure. Following selection, all patients were evaluated and treated for periodontal and dental health and received oral hygiene instructions until a clinically acceptable oral environment was achieved. CBCT and panoramic radiography were performed to evaluate the presence and height of the septum, the dimensions of the alveolar process, and the thickness and status of the sinus membrane. If the criteria for RBH (4–5 mm) and bone thickness (6.5 mm) were fulfilled, the requirements for three-dimensional restoration-driven implant placement were identified.

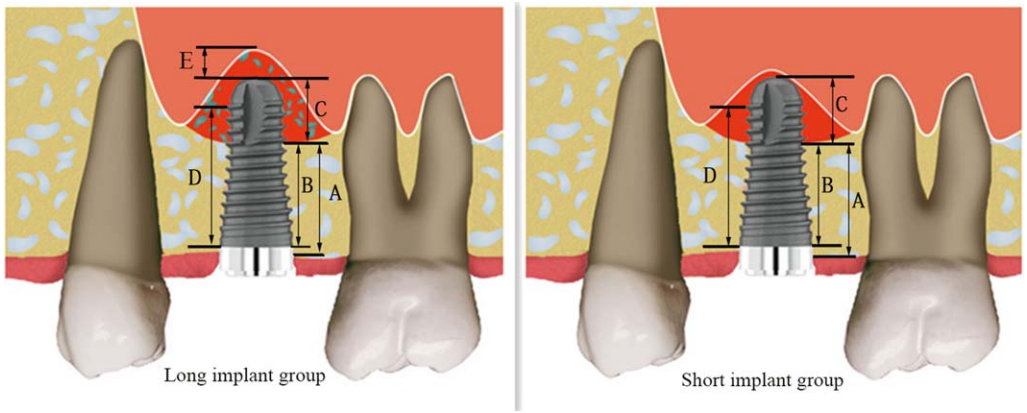

Figure 1 Schematic illustration of the evaluated radiographic parameters. *A*, residual bone height; *B*, distance from the smooth–rough implant interface to the most apical implant–bone contact. An increase in (B) corresponds to endosinus bone gain; *C*, implant length protruding into the sinus; *D*, distance from the most coronal bone–implant contact to the most apical implant thread. A decrease in (D) corresponds to crestal bone loss; *E*, distance from the apex of the implant to the border of the graft; E+C: apical height of the graft in the long implant group.

Surgical Procedure. All patients received prophylactic antibiotic therapy with 2 g of amoxicillin (500 mg of claritromycin in case of penicillin allergy) 1 hour before treatment. After surgery, amoxicillin (750 mg three times a day), Ibuprofen (600 mg three times a day), and chlorhexidine mouthwash (0.2% three times a day) were prescribed for 7, 4, and 10 days, respectively. Surgery was performed under local anesthesia with 4% articaine according to a standardized protocol.[20] In the long implant group, sinus augmentation was performed using the lateral window approach. A crestal incision with vertical releasing incisions was placed. After full-thickness flap elevation, autogenous bone chips were initially harvested with a bone scraper from the lateral cortex, and a lateral window was prepared using a round diamond bur. The bone was gently removed layer by layer until exposure of the Schneiderian membrane. Then, specifically designed hand instruments were used for elevation (Salvin Dental Specialties, Inc., Charlotte, NC). The sinus membrane was lifted to a degree that would allow the placement of 11- to 12.5-mm implants. The drilling sequence was completed using a crestal drill (Thommen Medical AG, Grenchen, Switzerland) for all implants. The implants were inserted into the recipient site using an insertion device and a hand ratchet. Large-particle Bio-Oss combined with approximately 10% autogenous bone was used as the graft material and inserted into the space between the sinus bone and elevated sinus membrane.

In the short implant group, a midcrestal incision was placed without any vertical releasing incisions for flap elevation. The implant sites were prepared with drills until a distance of at least 1 mm from the sinus floor. The sinus floor was fractured using light force applied with a mallet and carefully elevated into the sinus cavity to a height of no morethan 3 mm. Then, the hydrophilic implant surfaces were subjected to chairside conditioning for hydrophilicity according to the manufacturer's instructions. All implants were wetted with a 0.05 M NaOH solution (pH, 12.4) in the proprietary applicator immediately before placement and inserted using a standardized surgical procedure.

A nose-blow test was carried out to detect any perforation of the sinus membrane, and if positive, a double-layer collagen membrane was applied to close the rupture. The nose- blow test was repeated after drilling in the implant bed. If the membrane perforation was too large, the wound was closed, and surgery was performed later.

All implants were placed with a 1.0-mm machined neck resting at or slightly below the level of the alveolar crest. Healing abutments were placed on the implants and the flaps were sutured. If necessary, further soft excision was performed to allow close adaptation of the wound margins to the implant shoulder without submerging it.

Postsurgical Care. Patients were instructed to use a 0.2% chlorhexidine rinse for 20 s three times a day for 1 week, and their healing conditions were evaluated after 14 days.

Prosthetic Procedures. In the long implant group, after a 4-month healing period, conventional prosthetic procedures were performed to fabricate all-ceramic or metal–ceramic restorations that were inserted 2 or 3 weeks after the impressions were recorded.

In the short implant group, in the absence of clinical symptoms (pain or implant rotation), patients received a screw-retained or cement-retained provisional restoration 2 months after implant placement. Final restorations were fabricated 16 weeks after implant surgery.

Follow-Up Procedures and Clinical Assessments. The follow-up protocol included patient assessments every 3 months during the first year and 12 and 24 months after implant placement. Standardized panoramic radiographs were acquired immediately after surgery and 12 and 24 months after implant placement. All radiographs were obtained by the same operator with the same device (Planmeca ProMax Dimax3 Ceph, Planmeca) set at 60–62 kV and 8–12 mA with a 16-s exposure time and standardized positioning of the head and body. The primary and secondary outcome measurements were as follows:

Primary Parameters.

- Implant failure. Implant survival was assessed on the basis of the following criteria: absence of clinically detectable implant mobility, absence of pain or any subjective sensation, absence of recurrent peri-implant infection, absence of continuous radiolucency around the implant, and absence of progressive marginal bone loss. The mean annual vertical bone loss had to be <0.2 mm after the first year in function.[21]

Secondary Parameters.

- Peri-implant marginal bone level changes. The mesial and distal bone levels were measured as the distance between the top level of the implant shoulder and the most coronal visible point of bone–implant contact (DIB). For each implant, the DIB value was taken as the average of the mesial and distal measurements, and the DIB values calculated at each follow-up visit were compared with those calculated at baseline.
- Periapical endosinus bone gain. The difference in the sinus bone height before and after surgery indicated the endosinus bone gain. The net bone gain was expressed as the difference between the endosinus bone gain and crestal bone loss (Figure 1).
- The following parameters were additionally recorded for the mesial and distal implant surfaces: implant protrusion into the sinus and the vertical distance between the implant apex and the first most visible apical bone–implant contact, which indicated the implant length protruding into the sinus.
- All biological complications.

All clinical assessments were performed by a clinician who was not involved in the treatment of the patients. Radiographs were converted to TIFF format with a 600 dpi resolution and stored in a computer. The peri-implant bone level (bone resorption and gain) was measured using a computerized measuring technique with image analysis software (Digora, Soredex, Helsinki, Finland). Given that the distance between consecutive threads is 1.00 mm, internal calibration was performed for each radiograph by measuring the distance between four implant threads (3.00 mm) at least. Precision of the measuring system is 0.01 mm. The measurements were taken parallel to the implant axis and repeated three times for each mesial and distal side. To improve image analysis, image enhancement operations like sharpening, brightness, contrast, and adjustments were performed when necessary.

Statistical Analysis. All data were analyzed using a pre-established analysis plan. Bone level and endosinus bone gain measurements were gathered from the mesial and distal sides of the implant. Descriptive statistics, that is, means and standard deviations (SDs) and medians and and range-s, were computed. Differences in the amount of bone resorption were compared between groups using Fisher's exact chi-square tests. The resorption of alveolar bone was also assessed and compared between different types of crown materials using Fisher's exact chi-square tests and among implants placed with the flared neck resting at, above, or slightly below the crestal bone level using one-way ANOVA. All statistical comparisons were performed at a significance level of 0.05.

RESULTS

Forty-two patients were screened for eligibility. Of these, one patient who refused lateral sinus floor

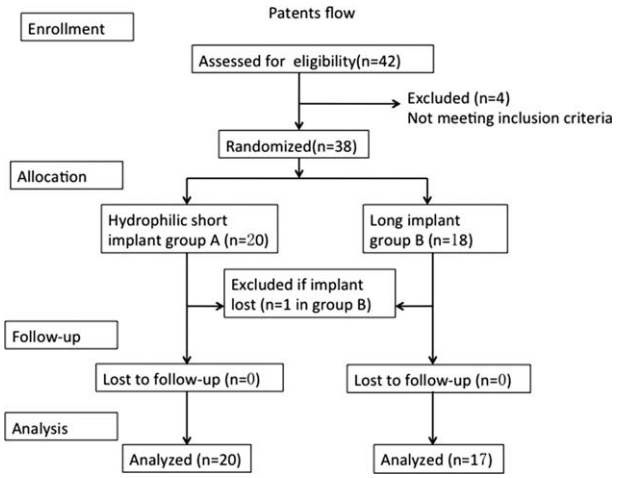

Figure 2 Study flowchart.

elevation surgery and three who refused randomization were excluded. Eventually, 38 patients were considered eligible and enrolled in this trial (Figure 2). The study population included 18 women (47.4%) and 20 men with a mean age of 49.4 ± 6.5 years (range, 34 to 60 years). The implants were inserted with an average torque of 35–40 N cm. The main baseline patient characteristics are presented in Table 2. The mean RBH in the hydrophilic short and long implant groups was 4.5 ± 0.39 mm and 4.35 ± 0.36 mm, respectively (Table 3).

PRIMARY OUTCOME MEASURE

Implant Survival Rates

No patient reported adverse effects after dental implant placement. Fifteen patients in the long implant group and five in the short implant group complained of postoperative discomfort without any untoward consequences.

Only one implant in the long implant group failed because of abscess formation after lateral sinus floor elevation surgery. This implant was removed and placed again after a 3-month healing period. Accordingly, the implant survival rate was 100% in the short implant group and 97.6% in the long implant group, with no significant differences between groups ($p > 0.05$).

All other implants remained stable, with no complications reported till the end of the study at 2 years. A total of 37 patients with 76 implants completed the study as planned.

Within 2 years after loading, two prosthetic complications occurred in the long implant group: repeated veneer fracture of a crown that was eventually fabricated again with a metallic occlusal surface and occlusal screw loosening that required retightening. In the short implant group, one cement-retained crown was retained by a screw because it could not be retained by cement.

SECONDARY OUTCOME MEASURES

Bone Resorption

Panoramic radiographs obtained immediately after surgery and at 2 years for all implants revealed no signs of continuous peri-implant radiolucency. Bone level changes at baseline and 1 and 2 years after surgery are shown in Figures 3 and 4. The mean change in the peri-implant bone level at 2 years was not significantly different between the short (0.35

TABLE 2 Patient and Intervention Characteristics

	Short implant	Long implant
Female	8 (40%)	10 (55.6%)
Mean age at implant insertion (years)	47.8	50.9
Total number of inserted implants	38	41
Patients who received one implant	7	4
Patients who received two implants	8	5
Patients who received three implants	5	9
Length of placed implants (mm)	6.5	11.0 or 12.5
Total number of 4.0-mm-diameter implants	10	12
Total number of 4.5-mm-diameter implants	20	21
Total number of 5.0-mm-diameter implants	8	8

TABLE 3 Radiographic Parameters Over 2 Years for 6.5-mm Hydrophilic Implants Placed with Simple Osteotome Sinus Floor Elevation Procedures and Long Implants Placed with Lateral Sinus Floor Elevation Surgery with Bone Grafting

Implant group	Short	Long	
Initial RBH	4.5 ± 0.39 (3.89–5.21)	4.35 ± 0.36 (3.29–5.11)	$p = 0.088$
Crestal bone loss	−0.35 ± 0.60 (−1.62–0.76)	−0.40 ± 0.71 (−2.31–0.78)	$F = 0.101$, $p = 0.751$
Endosinus bone gain	2.94 ± 0.81 (1.40–4.55)	10.19 ± 0.95 (7.77–12.21)	$p = 0.000$*
Implant protrusion length	(3.28 ± 0.78) (1.39–4.96)	(8.33 ± 0.91) (6.40–10.65)	$p = 0.000$*

*Statistically significant differences.
RBH = residual bone height.

mm ± 0.60 mm) and long implant groups (0.40 mm ± 0.71 mm; Figures 5 and 6).

There were no significant differences in bone resorption on the mesial side ($p = 0.244$) among implants placed with the flared neck resting at, above, or slightly below the crestal bone level, while that on the distal side differed significantly between implants placed with the flared neck resting below the crestal bone level and those with the neck resting at or above the crestal bone level ($p = 0.006$; Table 4). Alveolar bone resorption on the mesial ($p = 0.475$) and distal sides ($p = 0.371$) showed no significant differences between all-ceramic and porcelain-fused-to-gold crowns.

Endosinus Bone Gain

The endosinus bone height increased on all sides of the implants, with a mean bone gain of 2.94 ± 0.81 mm and 10.19 ± 0.95 mm in the short and long implant groups, respectively ($p < 0.01$) (Figures 3 and 4). At 2 years, the available bone height was 7.09 ± 0.98 mm (range, 4.75–9.76 mm) in the short implant group and 12.91 ± 1.07 mm (range, 9.96–15.15 mm) in the long implant group. The main outcomes are summarized in Table 3.

Surgical Complications

Rupture of the sinus membrane occurred in two of the short implant cases and in one of the long implant cases; however, the difference between the two groups was not statically significant. All lesions healed spontaneously with simultaneous implant placement. One implant in the long implant group was removed because of abscess formation after lateral sinus floor elevation surgery. Other postoperative

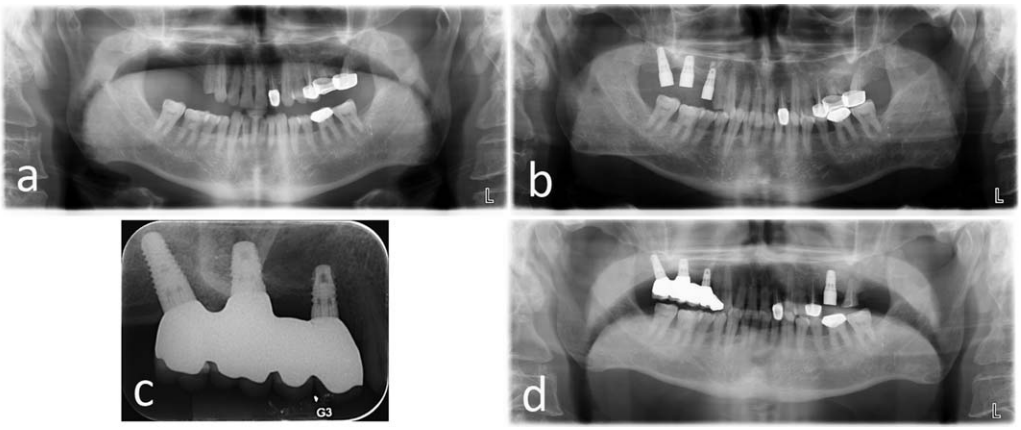

Figure 3 Radiographs after short implant placement. *A*, Preoperative radiograph; *B*, Radiograph obtained immediately after short implant placement with osteotome sinus floor elevation. Note the elevation of the sinus membrane; *C*, Prosthetic load radiograph; *D*, radiograph obtained at 2 years after short implant placement with osteotome sinus floor elevation. Note the stability of the bone level.

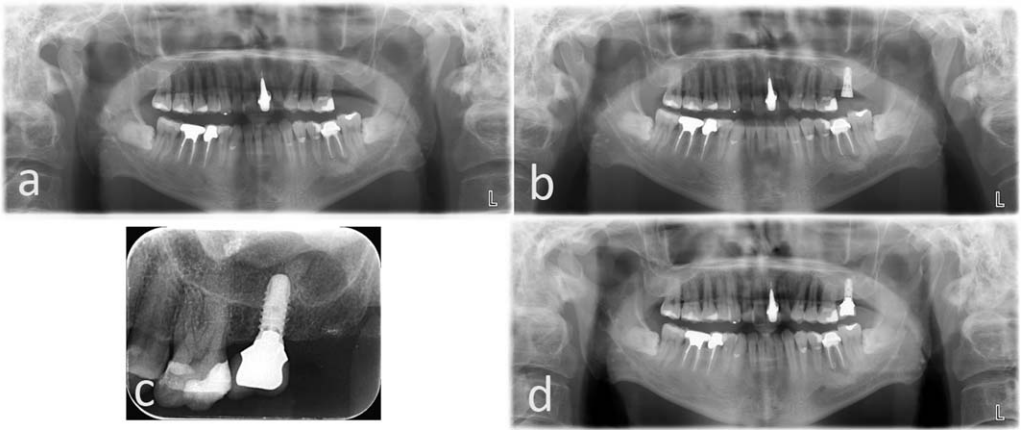

Figure 4 Radiographs after long implant placement. *A*, Preoperative radiograph; *B*, Radiograph obtained immediately after long implant placement with lateral sinus elevation. Note the radiopacity around implant; *C*, Prosthetic load radiograph; *D*, Radiograph obtained at 2 years. Note the stability of the bone levels.

complications, including nasal bleeding and postoperative headache, occurred in four of the short implant cases and in five of the long implant cases. There were no cases of benign paroxysmal positional vertigo (Table 5).

DISCUSSION

This study evaluated the performance of 6.5-mm implants placed with OSFE in comparison with that of standard long implants simultaneously placed with lateral sinus floor elevation surgery with bone grafting in severely atrophic posterior maxillae. The results suggest that short implants with a hydrophilic surface in such cases can be successfully loaded after 8 weeks.

In clinical practice, generally the rehabilitation of patients with an RBH $\leq$5 mm below the maxillary sinus utilizes a lateral wall approach.[22] In this study, there was no significant difference in the implant survival rate between the 6.5-mm short implant group with an initial RBH of 4.50 mm and the long implant group with an initial RBH of 4.35 mm (100% vs 95.2%). The mean change in the peri-implant bone level was comparable between groups, and systematic radiographic evaluation of the implants failed to identify continuous peri-implant radiolucency or bone loss of $>$1 mm during the observation period of 2 years in any case. When the subsinus bone height is between 4 and 5 mm, conventional treatment with lateral sinus augmentation is possible, and excellent long-term ($\geq$5 years) implant survival/success rates have been documented in these cases.[7] The utility of short implant placement with OSFE is controversial. In a prior study, 6-mm short implants placed with OSFE were considered high risk, with a 47.6% survival rate.[23] However, in this study, the survival rates for 6.5-mm implants placed with OSFE were comparable with those for long implants placed with lateral sinus floor elevation. According to Nedir and colleagues, the use of OSFE without grafting material can be advocated for a maxillary RBH of 4–8 mm.[24] The absence of grafting does not compromise the success of OSFE and implant survival. Bernardello and colleagues also proposed performed crestal sinus

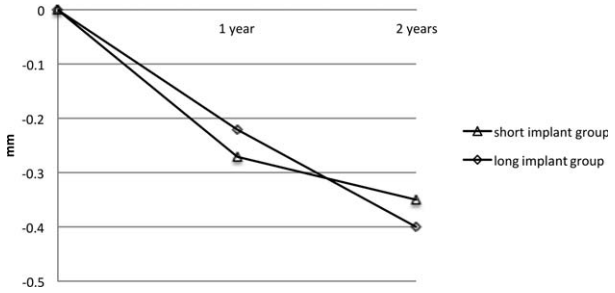

Figure 5 Bone level changes measured immediately after surgery and at 1 and 2 years after surgery.

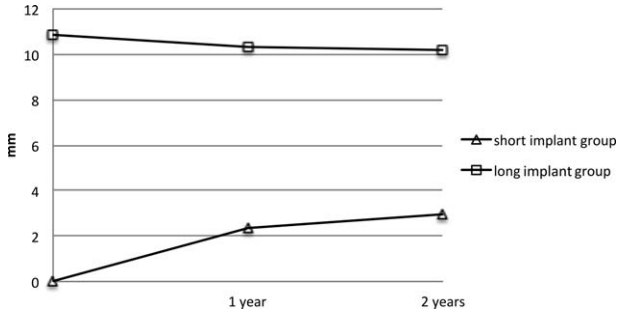

Figure 6 Endosinus bone gain measured immediately after surgery and at 1 and 2 years after surgery.

TABLE 4 Statistical Analysis to Evaluate the Influence of Implant Placement Level on Bone Resorption

	Mean difference	Std. Error	*p*
"−" versus "0"	0.883	0.287	0.012*
"−"versus "+"	0.930	0.338	0.029*
"0" versus "+"	0.047	0.343	1.000

*Statistically significant differences.
"−" = implant neck below the crestal bone.
"0" = implant neck at the level of the crestal bone.
"+" = implant neck above the crestal bone.

elevation with simultaneous implant placement and reported a success rate of 96.4% for sites with an RBH of 4–5 mm.[25] Studies by Cannizzaro and colleagues[9] and Esposito and colleagues[18] compared long implants inserted into maxillary sinuses augmented using the lateral window approach with that of 8-mm-long implants placed in sinuses augmented using OFSE procedures and found no significant differences at 1 year, although the failure and complication rates were higher with the more invasive procedure. The results presented here are consistent with these findings.

In this study, the mean endosinus bone gain was 2.94 ± 0.81 mm in the short implant group without grafting. There were no failures or adverse events associated with the placement of hydrophilic implants without grafting materials. The need for sinus space grafting after maxillary sinus floor elevation remains controversial. Most researchers place grafting materials at the osteotomy site that are condensed until the desired graft height is achieved.[26] However, Cricchio and colleagues concluded that the secluded compartment created by the elevation of the maxillary sinus membrane allowed bone formation without the requirement for any graft materials.[27] In cases treated with OSFE without grafting, Nedir and colleagues have shown 1-year endosinus bone gains of 2.5 ± 1.2 mm and 2.5 ± 1.7 mm and crestal bone losses of 1.2 ± 0.7 mm and 0.2 ± 0.6 mm in sites with mean RBHs of 5.4 ±2.3mm and 3.8 ±1.2mm, respectively.[28,29] This may be linked to increased endosinus bone gain and longer protrusion length into the sinus. Increased endosinus bone gain in this study could be a consequence of the hydrophilic properties of the implant surface. Endosinus bone gain is a complex process in which elevation of the sinus membrane creates a space in which serum and blood clot is stabilized, potentially stimulating peri-implant bone formation.[30] Absorption of proteins and macromolecules on the implant surface enable the fixation of fibrin fibers and infiltration of cellular components, to initiate the formation of new bone matrix.[31] A hydrophilic surface has been shown to enhance angiogenesis and improve blood clot stabilization. A high surface energy may also play an important role in improved bone regeneration.[32] Indeed, most recent histological data have demonstrated that hydrophilic titanium surfaces promoted bone regeneration in acute-type buccal dehiscence defects associated with submerged implants placed without additional graft material.[32] To date, two different technologies have been used and are commercially available to prepare hydrophilic dental implants: (i) SLActive (Straumann AG, Basel, Switzerland), which involves rinsing the titanium surface after the etching process under nitrogen protection, followed

TABLE 5 Incidence of Surgical Complication

	Short implant (*n* = 38)		Long implant (*n* = 41)	
Complication	Patients (*n*)	%	Patients (*n*)	%
Interoperative complications	2	10.0	1	5.6
Rupture of the sinus membrane	2	10.0	1	5.6
Postoperative complications	4	20.0	5	27.8
infection	0	0.0	1	5.6
Nasal bleeding	2	10.0	3	16.7
Postoperative headache	2	10.0	1	5.6
BPPV	0	0.0	0	0

BPPV = benign paroxysmal positional vertigo.

by storage in isotonic saline[33]; and (ii) INIcell, which involves chairside treatment of dental implants with aqueous sodium hydroxide.[34] Nedir and colleagues reported that the mean endosinus bone gain was 3.9 ± 1.0 mm after the placement of 8-mm SLActive implants without bone grafting.[11] Differences were probably a consequence of different initial RBHs and lengths of protrusion into the sinus.[11] The hydrophilic properties, different wettabilities and surface charges, and different topographies may have modified or accelerated osseointegration.[34]

The low bone density in the posterior maxilla is a risk factor for the failure of short implants, especially for the 6.5 mm-length implant used in the current study. According to Antoun and colleagues, compaction using osteotomes improves the quality of bone and the primary stability of implants. This technique is indicated for alveolar crests with a height of 4–5 mm and type III or IV bone.[35] Moreover, cancellous bone exhibits faster remodeling and can be easily influenced by implant surface modifications.[15] This study suggests that it is possible to load early (8 weeks) after 6.5-mm-long implants placed simultaneously in lifted sinuses. New and possibly improved implant surface modifications and designs, together with improved surgical techniques, can aid in successful short implant placement. Because bone density seems to represent the major determinant of primary stability in maxillary sinus augmentation, a previous study showed that tapered implants with a reduced thread pitch could achieve high primary stability, even when the initial RBH in the posterior maxilla was less than 6 mm.[29] The tapered implants with a tighter pitch used in this study compensated for the decreased length of engagement. It is important to preserve the marginal bone during implant placement and to place implants deeper than usual, so that the flared neck rests below the crestal bone level as required. As expected, the resorption of alveolar bone on the distal side differed significantly between implants placed with the flared neck resting below the crestal bone level and those placed with the neck resting at or above the crestal bone level, while there were no significant differences on the mesial side. Animal studies have suggested that hydrophilic implants are associated with greater bone–implant contact, an increase in implant stability, and a continued increase in implant stability in the early healing phase of 2–4 weeks.[36] Moreover, a previous study recommended the use of implants with a hydrophilic surface in areas of poor-quality bone.[37] The current study validates these findings from a clinical perspective and suggests that a mean of 4–5 mm of residual alveolar bone with a low crown-to-implant ratio in the posterior maxilla may be sufficient for providing primary stability.

During sinus floor elevation, the risks of complications must be considered, and the clinician must be prepared for appropriate management. Although the Schneiderian membrane can support an elevation of 4–8 mm, depending on the thickness and sinus morphology,[38] an elevation of 3 mm was reported to be safe according to the clinical complexity.[39] With the use of internally cooled drills with high torque and low speed, bone can be compacted as close to the final depth as possible, thus preventing direct contact with the sinus membrane and minimizing the risk of membrane perforation.[40] Perforation of the sinus membrane during the OSFE procedure occurs in 0–21.4% of implant-treated sites and postoperative infection occurs in 1.5% of patients.[41,42] Barone and colleagues reported a perforation rate of 25% and an infection rate of 5.6% in 124 treated sites using the lateral sinus floor elevation procedure.[43] Two perforations and one perforation occurred in the short implant group and the long implant group, respectively (10% vs 5.6%). However, these healed spontaneously with simultaneous implant placement. Since the Schneiderian membrane cannot be visualized during elevation, it is necessary to check its integrity. If membrane perforation has occurred, implants can be placed simultaneously, without grafting and this does not adversely affect the implant survival.

A limitation of this study was the systematic difference in the implant diameters. The sample size was small and a longer follow-up period would have been desirable. In addition, changes in bone height and endosinus bone gain were not analyzed with three-dimensional projections, which is known to be a more accurate and reliable technique. As 2D bone level change was measured as our outcome measurement, panoramic radiographs were advocated by the institutional ethics committee to decrease radiation exposure. To evaluate the potential risk of sinus membrane perforation, a CBCT and panoramic radiograph were performed to assess the presence and

height of the septum, the dimensions of the alveolar process, and the thickness and status of the sinus membrane.

CONCLUSIONS

This study shows that the 2-year performances of short hydrophilic implants placed with OFSE procedures are similar to conventional long implants placed with lateral sinus floor elevation with bone grafting in severely atrophic posterior maxillae. Hydrophilic surfaces may broaden the applicability of implants to more challenging clinical situations. Short implants may be a favorable choice for patients with an RBH of 4–5 mm under the maxillary sinus. Furthermore, implants with hydrophilic surfaces can be loaded early in the elevated sinus, which contribute to the favorable outcomes. Further clinical studies regarding the long-term performance of hydrophilic implants are required.

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