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Short Implants and Conventional Implants in The Residual Maxillary Alveolar Ridge: A 36-Month Follow-Up Observation

Authors' Contribution:
Study Design A
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Statistical Analysis C
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Manuscript Preparation E
Literature Search F
Funds Collection G

ABCDEF 1 Jakub Hadzik
BF 1 Maciej Krawiec
BF 1 Paweł Kubasiewicz-Ross
DF 2 Agata Prylińska-Czyżewska
CF 3 Tomasz Gedrange
ACDEFG 1 Marzena Dominiak

1 Department of Dental Surgery, Wrocław Medical University, Wrocław, Poland
2 Department of Prosthodontics, Oral Rehabilitation Clinic, Poznań Medical University, Poznań, Poland
3 Department of Orthodontics, Carl Gustav Carus Campus, Technical University Dresden, Dresden, Germany

Corresponding Author: Jakub Hadzik, e-mail: Jakub.hadzik@umed.wroc.pl
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Background: Short dental implants are considered an alternative method of treatment to the maxillary sinus elevation and bone augmentation procedure at the sites of a reduced alveolar ridge height.
The aim of the study was to determine the most effective therapeutic approach for a single tooth replacement in a reduced maxillary alveolar crest.

Material/Methods: We enrolled 30 partially edentulous patients having a residual crestal height of 6 mm and a minimal width of the alveolar ridge of 6–7 mm: 15 patients received regular dental implants (OsseoSpeed™ L11 Ø4 mm and L13 Ø4 mm) and the implantation was preceded by the sinus lift procedure from a lateral window approach with the application of a xenogeneic bone graft, whereas the remaining 15 patients received short implants (OsseoSpeed™ L6 mm Ø4 mm) without the sinus lift and augmentation procedure.
All implants were loaded with single non-splinted crowns. Radiological examination (CBCT, RVG) was performed before the surgery and after 36 months. Primary and secondary stabilization with Osstell ISQ® and Periotest® were assessed.

Results: Good results in primary and secondary stability were achieved in both systems. The marginal bone level (MBL) loss was low (0.22±0.46 mm and 0.34±0.24 mm, for short and conventional implants, respectively). No significant difference in MBL between groups was found.

Conclusions: Short implants can be successfully used to support single crowns in the lateral part of the maxilla.

MeSH Keywords: Maxilla • Prostheses and Implants • Sinus Floor Augmentation

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Background

Conventional implant treatment can be performed in the edentulous maxilla only when there is an adequate amount and quality of bone tissue. As a result of tooth loss and the natural process of alveolar bone remodelling, the walls of the alveolar ridge resorb [1,2]. Because of advanced bone resorption, the deficiency in the vertical dimension, and the presence of an extensive maxillary sinus, an insufficient amount of bone may be present. Implant placement in a resorbed alveolar ridge is impossible without bone augmentation in the maxillary sinus prior to the planned implantation [2–5].

Since the external sinus floor elevation technique was first introduced by Boyne and later by Tatum, it has proven to be very effective in increasing bone volume in edentulous maxillary areas [4,6]. Elevation and augmentation of the maxillary sinus can increase the bone height in the posterior area of the maxilla. Depending on the amount and quality of residual bone, elevation of the maxillary sinus floor (the sinus lift) must be performed as a one-stage surgical procedure during implantation, with access through the alveolar ridge and a preliminarily prepared implant bed or with a lateral approach (the open method). However, there are some general disadvantages of performing the sinus floor elevation, including the maxillary sinus being lined inside with the periosteum covered with respiratory epithelium (the Schneiderian membrane) [7]. The most frequent complication after the sinus lift is the perforation of that membrane [7–10]. Cho et al. [11] reported the rate of iatrogenic perforation of the Schneiderian membrane was 7% and 30% depending on the instruments applied (Piezosurgery and drill, respectively).

Many efforts have been made to develop alternative treatments for maxillary sinus floor elevation. For example, zygomatic implants for the management of atrophic edentulous maxilla and short implants to replace missing single teeth have been introduced. Implants with reduced length (short implants) have been successfully used to fit reduced alveolar bone and to avoid the need for sinus lift procedures. There is still some controversy over the definition of a short-length implant. For the purpose of this study, implants with a designed intrabony length of ≤6 mm were considered short.

The aim of the present study was to compare the efficacy of short implants and regular implants in the lateral aspects of the maxilla of the limited height of the alveolar ridge.

Material and Methods

The study protocol was approved by the local ethics committee (the Bioethics Committee at Wroclaw Medical University, approval no. KB 427/201). All patients gave 2 written consents: the first was general consent to have dental implants placed, and the other consent involved participation in the study. The study was conducted in full compliance with the Declaration of Helsinki. The study material consisted of 30 patients (20 females and 10 males) ages 26–64 years (mean age, 45.5 years).

Inclusion criteria

To qualify for the study, the patients had to be age >18 years and have single missing teeth in the lateral aspect of the maxilla. Additional inclusion criteria were:

- minimal apicocoronal height of the alveolar ridge of 6 mm in the region of the implant insertion in the pre-surgical qualification;
- minimal width of the alveolar ridge of 6–7 mm in the region of interest;
- HKT (height of the keratinized tissue) higher than 2 mm;
- API ≤35 (approximal plaque index);
- PI ≤25 (plaque index).

Exclusion criteria

The criteria that disqualified patients from the study were previous graft procedures in the area of interest and systemic or local diseases that could compromise healing or osteointegration. Smokers and patients with bruxism were also excluded from the study.

Surgical treatment

The patients were randomly divided into 2 groups according to the method of treatment provided. The first group (G1) of n=15 patients had conventional dental implants (OsseoSpeed™ L11 Ø4 mm and L13 Ø4 mm) placed, preceded by the sinus lift procedure from a lateral window approach with the application of the Xenogeneic bone graft Geistlich Bio-Oss® [Geistlich AG, Wolhusen, Switzerland] (Figures 1–3). The other group (G2) of n=15 patients had short-length implants (OsseoSpeed™ L6mm Ø4mm) placed without the sinus lift and augmentation procedure (Figure 4).

Preoperatively, the patients were pre-medicated with antibiotics. The surgical procedure was performed with induced local anaesthesia. All patients were instructed to rinse their mouths with 0.12% chlorhexidine solution (twice a day until suture removal) and were given antibiotics and analgesics. Non-resorbable sutures were removed 7–14 days later.

Implant loading

Six months after implant placement, an impression of the implant was made and a final restoration was made and

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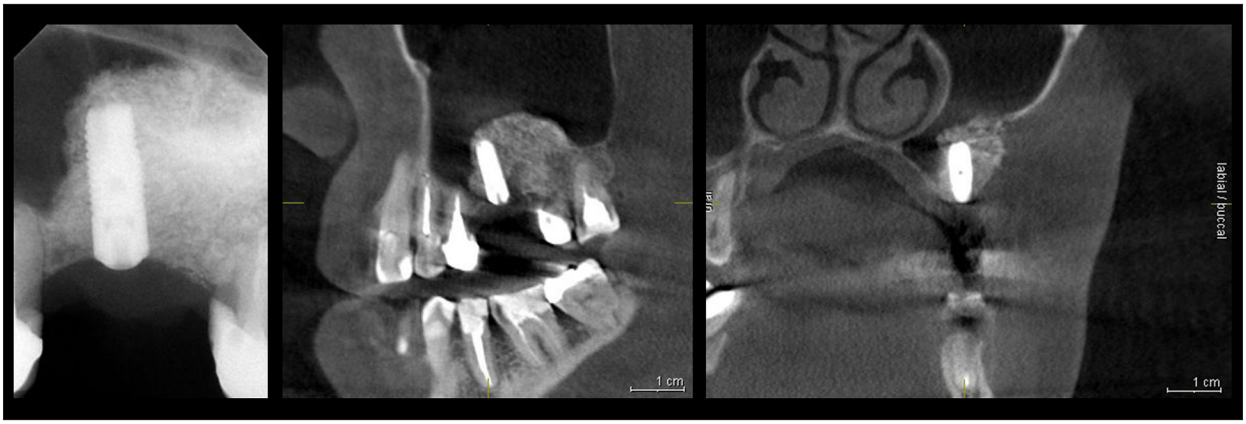

Figure 1. RVG, CBCT: OsseoSpeed™ regular implant. T0, Initial.

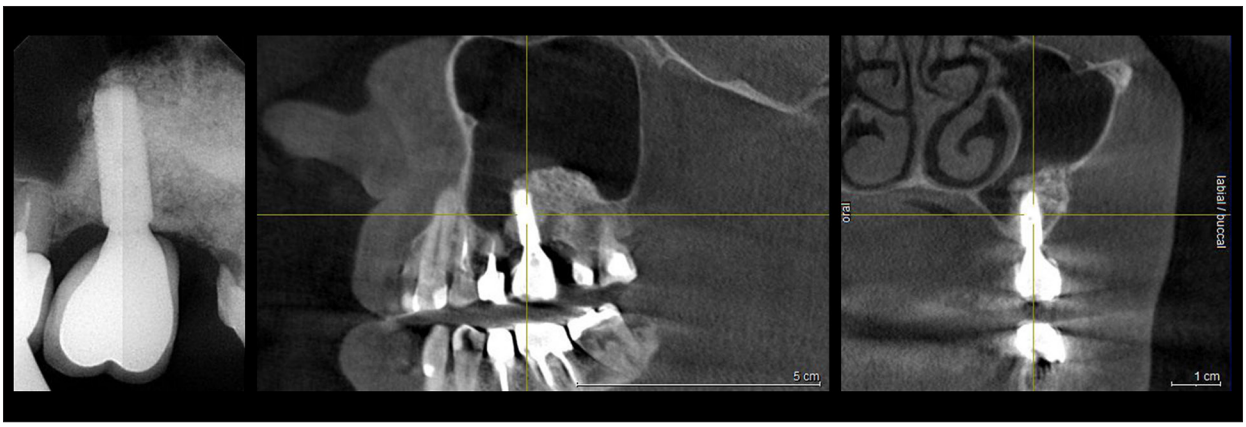

Figure 2. RVG, CBCT: OsseoSpeed™ regular implant. T2, 36 months.

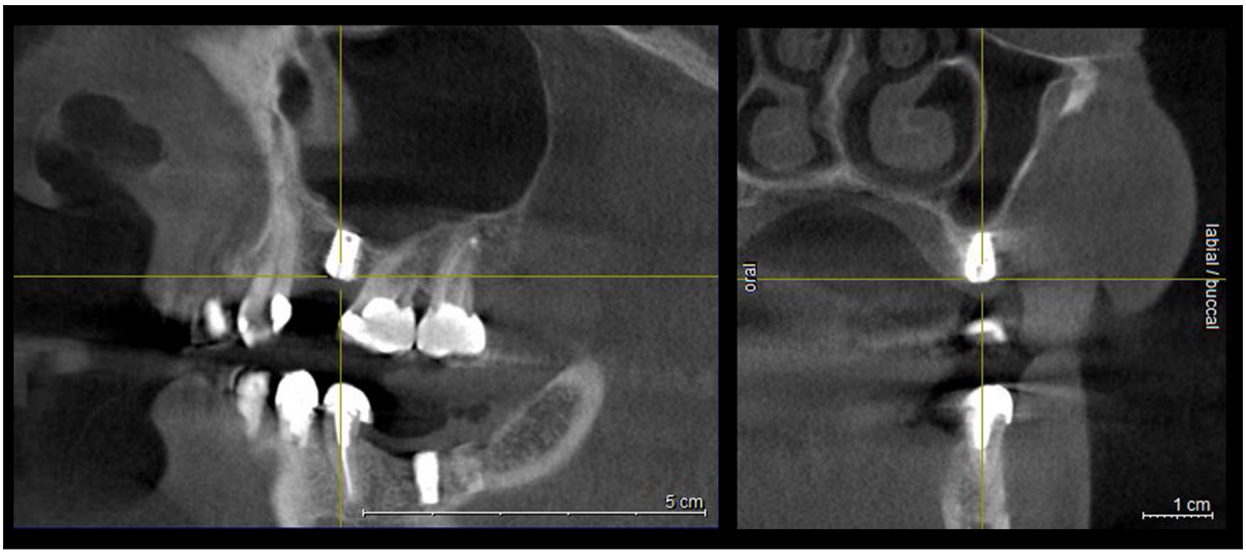

Figure 3. RVG, CBCT, OsseoSpeed™ short implant, T0, Initial.

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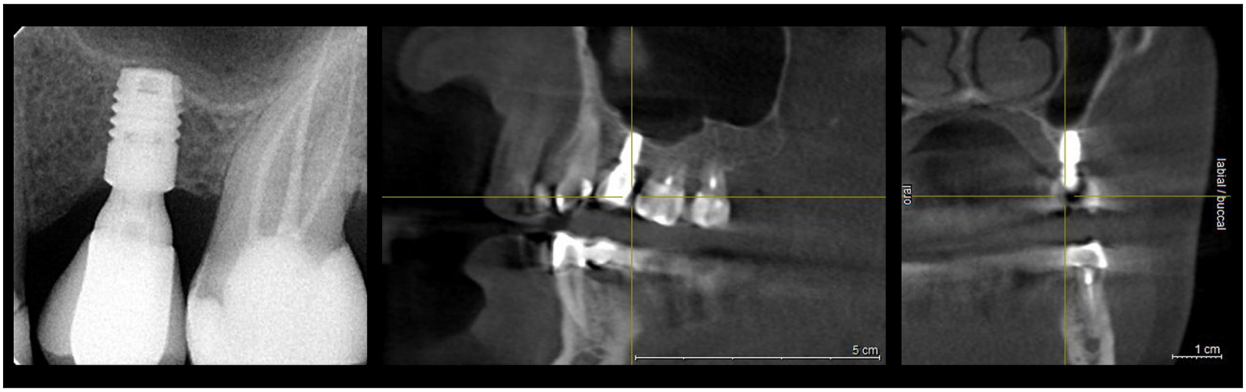

Figure 4. CBCT, OsseoSpeed™ short implant, T2, 36 months.

cemented; all implants were loaded with single non-splinted crowns.

Radiographic examination, clinical examining, follow-up

Before the surgery and after 36 months following it, the CBCT (Cone Beam Computed Tomography) [Galileos® D3437, Sirona Dental, Germany], and RVG [Visualix® eHD, Gendex Dental Systems, USA] examinations were performed to estimate the width and height of the alveolar ridge to assess the marginal bone loss (MBL). The assessment of the primary and secondary stabilization with Osstell ISQ® [Osstell, Sweden] was performed after the surgical procedure and before implant loading. Periotest® [Periotest Classic, Medizintechnik Gulden, Germany] was performed after the surgery, after 6 months, and after 36 months following it. The early healing index (EHI) was measured during wound healing. Pocket deep probing (PPD) was analyzed around the implant at 4 measurement points. The height of the keratinized gingiva (HKT), clinical attachment level (CAL), and the recession depth/width (RD/RW) were clinically measured with a dental periodontal probe with a millimeter scale.

Statistical analysis

Statistical analysis was performed using GraphPad Prism 6 software [GraphPad Software, Inc., USA]. The paired *t* test, Wilcoxon test, Pearson test, and Spearman test were carried out. All data are given as means ± standard deviation (SD). $P<0.05$ was considered statistically significant.

Results

We successfully placed 15 implants L6 mm Ø4 mm, 10 implants L11 Ø4 mm, and 5 implants L13 Ø4 mm. One implant in Group 2 was lost before loading. We decided not to include the lost implant into the statistical analysis because the loss occurred due to the patient's evident poor compliance, no cooperation during the treatment period, and directly ignoring the doctor's recommendations. Moreover, this patient did not go to the control visits required by the study protocol.

Group 1 [G1]:

T0, Before Surgery: The mean value of the alveolar bone height measured in the area of interest was 5.88±1.37 mm and the alveolar bone width was 9.0±2.3 mm. The mean measurement of the HKT at the implant site before the surgery was 2.7±1.64 mm. The mean measurement of implant primary stability after placement using Osstell was 58.67±12.3 ISQ. Moreover, the pain level measured using the VAS scale was 5.1±1.4.

T1, 6 months: The mean measurement of the HKT at the implant site was 2.83±1.29 mm. Secondary implant stability was measured using Osstell and Periotest (81±5,82 ISQ; and 1.8±3.61 PTV respectively). The average recession was measured: RW 1.12±1.38 mm, RD 0.42±0.79 mm, PPD 2.67±0.65 mm, and CAL 3.0±0.95 mm.

T2, 36 months: The final height of the alveolar bone base in the area of interest in this group was 15.48±1.32 mm and the width of the bone was 8.58±2.03 mm. The average HKT was 1.73±1.1 mm. The secondary stability was measured using Periotest 0.93±3.39 PTV. The mean measurement of the MBL based on radiographs was 0.22±0.46. Recession parameters were measured: RW 0.33±0.61 mm, RD 0.167±0.39 mm, PPD 3.17±1.27 mm, and CAL 3.33±1.5 mm.

Group 2 [G2]:

T0, before surgery: The height of the alveolar bone base in the area of interest in this group was 7.4 ±1.45 mm and the bone width was 8.46±1.29 mm. The average measurement of the HKT was 3.67±1.57 mm. The primary stability was measured with Osstell 64.8±13.27 ISQ and the pain level was measured using the VAS scale and was 1.47±0.99.

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Table 1. Osstell ISQ Implant stability. Measured in Implant Stability Quotient [ISQ].

	Group 1	Group 2	Paired t-test P-value
Primary stability T0 (initial)	58.67±12.3	64.8±13.27	0.1826
Secondary stability T1 (6 month)	81.0±5.82	77.2±8.34	0.2119
Paired t-test P-value	<0.0001	0.0018	

Table 2. Periotest Implant stability. T1 (6 months) and T2 (36 months).

	Group 1	Group 2	Paired t-test P-value
Primary stability T1 (6 month)	1.8±3.61	5.2±7.63	0.2119
Secondary stability T2 (36 month)	0.93±3.39	1.0±2.7	0.782
Paired t-test P-value	0.5349	0.0397	

Table 3. Alveolar dimension changes comparison at T0 (initial) and T2 (36 months).

Group 2	Alveolar height; T0	Alveolar height; T2.	Alveolar width; T0	Alveolar width; T2
Mean	5.888	15.48	9.054	8.578
SD	1.737	1.32	2.298	2.028
P value	0.0001		0.1509	
Test	Wilcoxon		Paired t test	
Significant	Yes		No	
Group 1	**Alveolar height; T0**	**Alveolar height; T2.**	**Alveolar width; T0**	**Alveolar width; T2**
Mean	7.399	7.449	8.457	8.17
SD	1.453	1.348	1.292	1.428
P value	0.7708		0.2276	
Test	Paired t test		Paired t test	
Significant	No		No	

T1, 6 months: The mean HKT was 3.27±1.19 mm. The mean secondary implant stability was measured using the Osstell device and Periotest (77.2 ±8.34 ISQ and 5.2±7.63 PTV respectively). Recession parameters were: RW 0.6±1.3 mm and RD 0.6±1.3 mm.

T2, 36 months: The final height of the alveolar bone base in the area of interest in this group was 7.45±1.35 mm and the bone width was 8.17±1.43 mm. The HKT was 2.27±0.96 mm on average. Secondary stability was checked using Periotest 1.0±2.7 PTV. The mean MBL was 0.34±0.24 mm. Recession parameters were RW 1.27±1.87 mm, RD 0.67±1.23 mm, PPD 2.53±0.83, and CAL 3.07±1.39 mm.

Initial stability evaluated with Ostell (T0) in the G2 short-length implant group compared to G1 regular implant group was higher (64.8±13.27 ISQ *vs.* 58.67 ±12.3 ISQ, respectively); however, after 6 months (T1) a higher increase in stability was observed in G1 than in G2. Finally, after 6 [36] months, higher stability results were achieved in G1 than in G2, but the differences were not statistically significant (81±5.82 ISQ and 77.2± 8.34 ISQ, respectively) (Table 1). The evaluation of implant stability with Periotest® after 6 months (T1) and after 36 months (T2) also showed positive results of secondary implant stability in both groups. However, the results in T1 were better for G1 compared to G2 (1.8±3.61 and 5.2±7.63, respectively), but the improvement in the implant secondary stability was observed in T2 for both groups (G1 0.93±3.39 and G2 1.0±2.7) (Table 2). The amount of alveolar bone in G2 where short-length implants were placed remained stable. The initial alveolar bone base height in the area of interest in this group was 7.4±1.45 mm and the width was 8.46±1.29 mm; the values measured after 36 months were 7.45±1.35 mm in terms of the height and 8.17±1.43 mm in terms of the width (Table 3). The marginal bone level loss was low (0.22±0.46 mm and 0.34±0.24 mm for G1 and G2, respectively), and was similar in both tested groups. No significant difference in the MBL between short-length implants and conventional groups was found (Table 4). No correlation was found in the statistical analysis between the keratinized gingiva loss and the MBL. Still, the amount of keratinized gingival remained at a minimum amount of 1.73±1.1 mm for G1 and 2.27±0.96 mm for G2 and

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Table 4. Marginal bone level (MBL).

	Group 1	Group 2	Wilcoxon test
T2	0.22±0.46 mm	0.34±0.24 mm	P=0.1229

did not impair the bone level (Table 5). The comparison of the VAS scale pain level in the intragroup analysis showed a statistically significant higher pain level in G1 compared to G2.

Discussion

When a deficiency in the vertical dimension and/or the presence of extensive maxillary sinus leads to an inadequate amount of bone for implant placement, maxillary sinus lift prior to the planned implantation must be performed.

Osteotomy of the alveolar ridge necessary during the lateral window approach sinus lift may be performed with various surgical instruments, such as conventional diamond drills, trephine burs used on a low-speed hand piece with water cooling, Piezosurgery, or a laser for hard tissues [4,12–15]. The most frequent complication after the sinus lift is perforation of the Schneiderian membrane. Wallace et al. report the rate of iatrogenic perforation of the Schneiderian membrane to be 7% and 30%, depending on the instruments used (Piezosurgery and drill, respectively) [15]. The data presented by Del Fabbro et al. in the Systematic Review of Long-Term Implant Survival of 6500 implants in 2149 patients in the Grafted Maxillary Sinus estimate the implant survival rate at 93.7%. [16]. However, the long-term results of the implantation in a grafted maxillary sinus are high, the operation site morbidity is high, and the procedure is technically demanding. Moreover, the period of healing and pain is also of significance. The results of this particular study in the intragroup analysis indicated a statistically significant higher pain level in G1 compared to G2. This may have been caused by an additional sinus floor elevation procedure in G1.

An alternative method of tooth replacement was introduced several years ago. To avoid open maxillary floor elevation surgery, the placement of short dental implants may be considered. There is still some controversy over the definition of a short-length implant. According to Tawil and Younan [17], an implant ≤10 mm is considered short, whereas Nisand and Renouard [18] define a short implant as a designed intrabony length of ≤8 mm and define an extra-short implant as a device with a designed intrabony length of ≤5 mm.

It was always believed that to achieve good implant stability, it is essential to place the longest implants possible in every case to improve bone-to-implant contact and the crown-to-implant ratio. However, current knowledge in implant dentistry demonstrates that bone-to-implant contact may also be improved with the use of micro-rough surfaces and new implant designs. A very important factor influencing the success of treatment with short implants is the type of surface. Surface modification may not only increase surface area, it may also affect cell morphology to influence osteointegration positively, and thus it may contribute to overcoming the adverse effects of length reduction [18–22]. There are many methods for increasing the dental surface roughness, although the combination of sandblasting and acid-etching (SLA) is the most commonly used method and is of great relevance. Histological parameters of SLA titanium implant osseointegration have been widely documented in the literature through tests on animal models. By inserting titanium implants with SLA® and SLActive® surface in minipigs' jaws, Buser et al. made a comparative histological

Table 5. Intragroup statistical analysis T0 (initial) and T2 (36 months). Alveolar height, alveolar width, HKT, RW, RD.

Group 2 *vs.* group 1 T0 (initial)	Alveolar height	Alveolar width	HKT	RW	RD	Pain
P value	0.0477	0.4098	0.0634	0.597	0.3308	<0.0001
Test	Paired t test	Paired t test	Paired t test	Wilcoxon	Wilcoxon	Wilcoxon
Significant	Yes	No	No	No	No	Yes
Group 2 *vs.* group 1 T2 (36 months)	**Alveolar height**	**Alveolar width**	**HKT**	**RW**	**RD**	
P value	<0.0001	0.6912	0.1782	0.25	0.5	
Test	Paired t test	Paired t test	Paired t test	Wilcoxon	Wilcoxon	
Significant	Yes	No	No	No	No	

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evaluation of the osseointegration of implants with these surfaces; after 2 weeks of healing the SLActive® implants showed a bone implant contact (BIC) of 49% for SLActive® and 29% for SLA®, after another 2 weeks the values were 82% for SLActive® and 67% for SLA®, respectively, and in the final evaluation after 8 weeks from implantation the values were 78% for SLActive® and 75% for SLA® [23]. A study by Schwarz et al., based on tests in dog models, showed that the BIC value for SLA implants was 55% [24]. In a study by Bornstein et al., based on the animal model of a beagle dog, a histomorphometric comparative assessment of titanium implants osseointegration with SLA® surface was also performed. The extraction phase included premolars bilaterally. The healing period of unloaded implants and observation period was 2 and 4 weeks. The BIC values were different in 2-week observations and were 29% for the SLActive® surface and 24% for the control SLA®, and after 4 weeks of healing, the values evened out and both achieved 39% [25].

Recent review studies indicate that short implants with a modified surface and design may represent a valid alternative to sinus lift procedures and even to a longer implant in non-augmented bone [21,26]. These observations correspond with the results of the present study, in which the treatment effect was similar between the short implant group (G2) and the traditional implants with an additional maxillary sinus floor elevation procedure (G1). The good results in primary and secondary stability with Osstell® was achieved in both implant systems. A statistically significant increase in stability observed during 6 months in G1 may suggest that lower primary stability was caused by the placement of the dental implant in the graft material after the simultaneous lateral window approach sinus floor elevation. The evaluation of Periotest® after 6 months (T1) and after 36 months (T2) also demonstrated good results in terms of secondary implant stability in both groups.

These findings proved that a significant negative association between the length of an implant and the marginal bone loss can be found [27,28]. In our study, the determination of the marginal bone level was based on radiographic measurements after 36 months. However, the results of the present study do not directly correspond with the literature on this issue.

Some studies showed that there is not enough substantial evidence to support the idea that proper height of keratinized tissues (HKT) around implants is needed to maintain health [29,30]. However, there are publications supporting the need for a minimum amount of keratinized gingiva around implants to achieve stable treatment results [31]. The relationship between the bone level and an attached gingiva appears to be indirect and is rather associated with a positive effect on the plaque accumulation and gingival inflammation, which can accelerate the marginal bone loss [21,32,33]. In the present study, a reduction in the amount of keratinized gingiva was observed in both groups when comparing the initial state and the state after 36 months; however, no correlation was found between the keratinized gingiva loss and the MBL in statistical analysis.

Conclusions

Short implants can be successfully used to support single crowns in the lateral part of the maxilla. Moreover, the use of short implants in clinical practice reduces the need for complex and technically demanding surgeries, thus reducing morbidity and postoperative discomfort.

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